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16. ABSTRACT

A three-year project was conducted by the California State Water Resources Control Board to determine methods of preventing and correcting erosion problems which severely effect the quality of the waters of the State of California. Two-project sites were chosen in the vicinity of the Lake Tahoe basin in California. One project site, Northstar-at-Tahoe, is a well planned and constructed residential-recreational development constructed in the early 1970s. The cost of extensive predeveloped planning and erosion control at Northstar is currently less that $400 per developed unit or residential lot. With ultimate planned build-out, costs are expected to be reduced to $220 per developed unit. The other project site, Rubicon Properties - Unit No. 2, is an extremely poorly planned and constructed residential subdivision development constructed in the late 1950s and early 1960s. The cost of complete corrective erosion control at Rubicon Properties would range from $1,000 to $3,000 or more per residential lot.

At both project sites, extensive demonstrations were made of predevelopment planning concepts, construction techniques, and corrective measures which may be used to substantially reduce erosion and sedimentation problems associated with developments which are typical to the subalpine to alpine Lake Tahoe region of California. Analyses were made to determine cost and effectiveness of the various erosion control techniques which were demonstrated at the project sites.

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Lake Tahoe Region of California

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DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

Lake Tahoe Region of California

by

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Alvin L. Franks

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Sacramento, California 95801

Demonstration Grant No. S803181

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and governmental concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This erosion control project and report is intended to assist the State and Regional Boards and other responsible entities in abating sediment and erosion problems in existing residential developments and insuring that adequate pollution control technology is incorporated into future developments. Only through vigorous control of existing pollution problems and the absolute prevention of future problems from developing can high quality waters be protected for current and future generations.

Francis T. Mayo
Director
Municipal Environmental Research
Laboratory

ABSTRACT

A three-year project was conducted by the California State Water Resources Control Board to determine methods of preventing and correcting erosion problems which severely effect the quality of the waters of the State of California. Two-project sites were chosen in the vicinity of the Lake Tahoe basin in California. One project site, Northstar-at-Tahoe, is a well planned and constructed residential-recreational development constructed in the early 1970s. The cost of extensive predeveloped planning and erosion control at Northstar is currently less than $400 per developed unit or residential lot. With ultimate planned build-out, costs are expected to be reduced to $220 per developed unit. The other project site, Rubicon Properties - Unit No. 2, is an extremely poorly planned and constructed residential subdivision development constructed in the late 1950s and early 1960s. The cost of complete corrective erosion control at Rubicon Properties would range from $1,000 to $3,000 or more per residential lot.

At both project sites, extensive hydrologic and water quality monitoring programs were conducted to determine erosion rates and their impact upon aquatic ecosystems. Monitored parameters included precipitation, snow depth, stream flow, suspended sediment and concentration, and benthic macroinvertebrate communities. Postdevelopment erosion rates at Northstar are estimated to be 100 percent above predevelopment levels, resulting in only minor perturbations of the benthic macroinvertebrate community of West Martis Creek. Postdevelopment erosion rates within Rubicon Properties are estimated to be over 10,000 percent above predevelopment levels, resulting in up to 99 percent destruction of the benthic macroinvertebrate community in Lonely Gulch Creek. At both project sites, extensive demonstrations were made of predevelopment planning concepts, construction techniques, and corrective measures which may be used to substantially reduce erosion and sedimentation problems associated with developments which are typical to the subalpine to alpine Lake Tahoe region of California. Analyses were made to determine cost and effectiveness of the various erosion control techniques which were demonstrated at the project sites.

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SECTION I

INTRODUCTION

In July of 1974, the California State Water Resources Control Board (State Board) was awarded a Demonstration Grant by the United States Environmental Protection Agency (EPA) to conduct a three-year project, "Demonstration of Erosion and Sediment Control Technology". The State Board chose the Lake Tahoe Basin vicinity of the Sierra-Nevada mountains as a candidate for this demonstration because of the increasing concern over the impact that development and construction activities are having in this region. The results of this project will be used by the State Board as a guide to the correction of existing and the prevention of future erosion-related water quality problems within the Sierra-Nevada mountains of California.

The State Board and California Regional Water Quality Control Board, Lahontan Region, (Regional Board) are concerned about the impacts which erosion and sedimentation from man's activities are having on water quality and the aquatic environment. In the Lake Tahoe Basin, water quality related erosion problems are manifest in a variety of ways even to the casual observer. The most obvious impact is the increased turbidity during high-surface runoff conditions, such as periods of snowmelt or rainstorms. After short, intense summer rainstorms, the office of the Regional Board in South Lake Tahoe is frequently contacted by irate vacationers and local homeowners complaining about the unsightly brown water flowing into streams tributary to Lake Tahoe. A certain degree of the suspended sediment flowing to Lake Tahoe is from natural sources. However, what few people seem to realize is that land disturbances associated with the construction and use of homes, roads, schools, motels, parking lots, and other facilities which allow hundreds of thousands of visitors and residents to enjoy Lake Tahoe each year can vastly increase the rate of erosion and sediment yield from a particular area. As an example, a study and recent report conducted by the California Resources Agency finds that construction and development of about 30 percent of the Upper Truckee and Trout Creek watersheds tributary to Lake Tahoe have significantly increased erosion and sediment yield of these two streams over what may be considered "natural levels" (1).

Aside from the lowered aesthetic appeal of sediment laden waters, there are other more subtle and potentially more serious effects. A recent report published by EPA identified eroded sediments as constributing to the eutrophication or enrichment of Lake Tahoe in at least two ways (2):

- By transporting associated nutrients, such as nitrogen, phosphrous, and iron, to Lake Tahoe.
- By providing a suspended substrate (or microscopic platforms) which support bacterial growth.

Lake Tahoe is renowned for its crystal clarity. This is primarily due to its sterile or nutrient deficient condition which is a direct result of the small watershed area to the water volume ratio of the Lake Tahoe Basin. The total land surface area which contributes runoff to Lake Tahoe is only slightly more than 1½ times the surface area of the Lake itself. As a result, naturally eroded sediments and nutrients are contributed to Lake Tahoe at a very slow rate. Evidence is accumulating, however, indicating that man-made developments which surround Lake Tahoe are rapidly accelerating the rate of nutrient and sediment transport to the Lake. This is particularly noticeable in the littoral or shallow near-shore areas which initially receive the increased sediment load and attached nutrients transported from the disturbed watersheds. In recent years, many Lake Tahoe shoreline residents and visitors have complained that rocks in some near-shore areas are much more "slippery and slimy" than they had been in the past. The slime they refer to is certainly attached algae. This is verified by recent investigations indicating that the rate of algal growth in Lake Tahoe increased 90 percent during the period from 1960 to 1971 (2).

Not only do suspended sediment laden waters have a definite impact on the Lake's water quality, they also have an impact on the aquatic life found in streams. The impact on streams flowing in heavily urbanized watersheds tributary to Lake Tahoe has been well documented (1,2,3). At one of the project sites, aquatic life in a stream receiving eroded sediments has been reduced up to 99 percent. The sediment laden waters reduce aquatic life by two basic mechanisms:

- Deposition of suspended sediments
- Scouring of the stream beds

Sediment deposition will bury and smother aquatic life, thereby substantially reducing their numbers. The scouring effect of heavily suspended sediment laden waters during runoff periods is roughly equivalent to "sandblasting" insect larvae and other aquatic life. Few species are able to withstand such a two-pronged attack on their environment.

The Regional Board, the state agency responsible for adopting and enforcing water quality standards in the California portion of the Lake Tahoe Basin, is taking a leading role in preventing degradation of surface waters by erosion and sedimentation. In 1975, the Regional Board adopted water quality objectives for all of the Lake Tahoe Basin which, once achieved, will limit the impact that erosion and sedimentation induced by man's activities will have on the Lake Tahoe Basin.

The problem now facing the State Board, the Regional Board, and all other agencies and individuals interested in preserving the water quality of the Lake Tahoe Basin is identifying methods and procedures which may be used to eliminate problems of the past, to prevent problems of the future, and to achieve established water quality objectives.

Once a method is identified, the Regional Board can order the developer to use specific methods through discharge requirements. In contrast to the situation with wastewater treatment plants, California Law (Water Code, Section 13360) permits the Regional Board to prescribe items required, such as subsurface drains, rock walls, etc., for erosion and drainage control.

The purpose of the Demonstration of Erosion and Sediment Control Technology Project is to provide a means of identifying the most cost-effective methods and procedures required to achieve these ends.

A. Project Sites

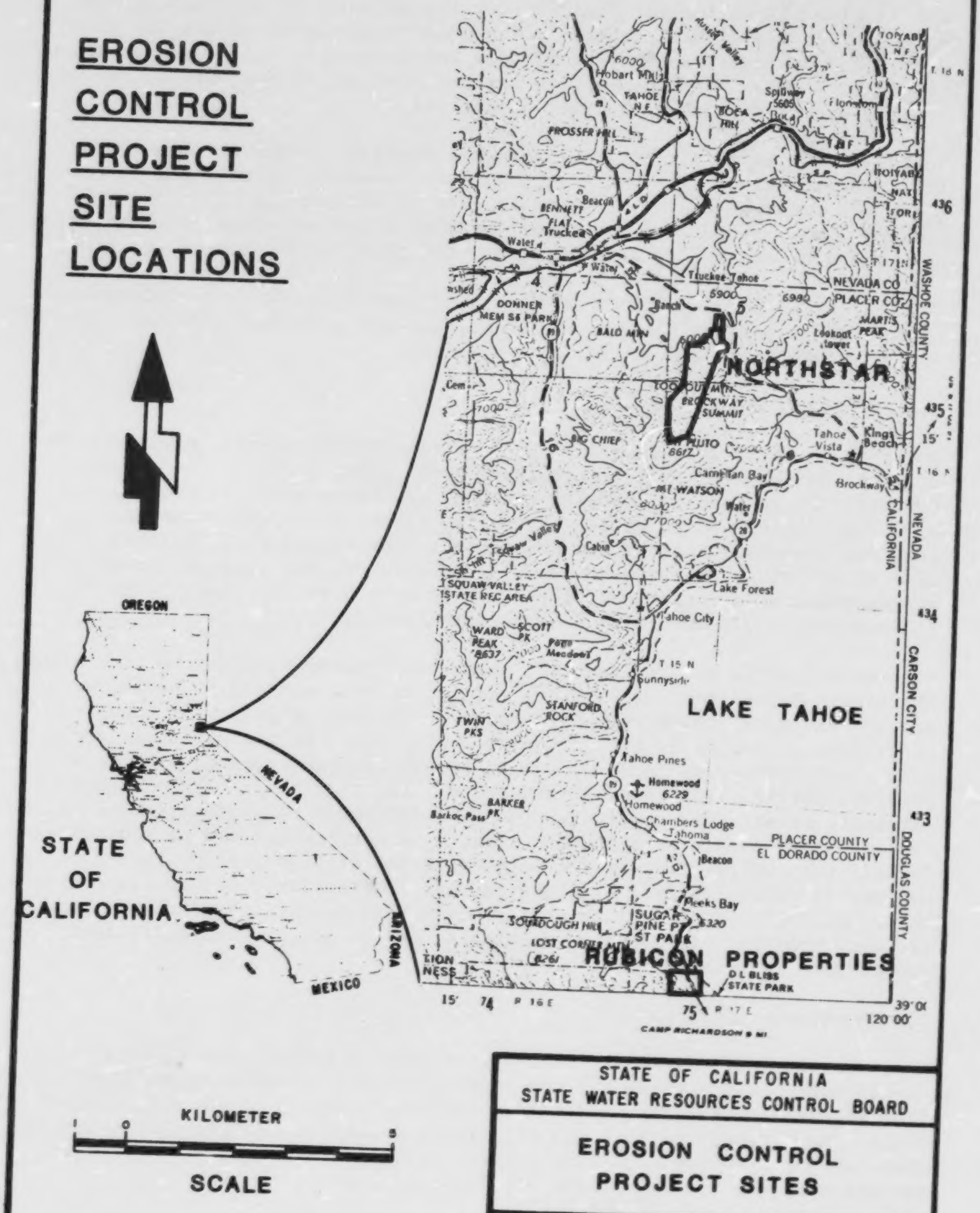
Two project sites were chosen as part of the erosion control demonstration project (See Figure I-1). Initially, Northstar-At-Tahoe, a year-round recreational-residential complex north of the Tahoe Basin in the Truckee River watershed, was selected. Extensive planning and environmental concern has been exhibited by its developers. The second site, Rubicon Properties Subdivision, on the west shore of Lake Tahoe, was selected because it represented the opposite end of the spectrum -- a poorly planned, poorly constructed, environmentally unsound development.

Both developments are located well above the typical winter snow line within the Sierra-Nevada mountains of California, an area subject to harsh, cold winters and warm, relatively dry summers. The vast majority of the precipitation occurring in the region typically comes in the winter as snow. Brief, but frequently intense, summer rainstorms can cause considerable erosion, particularly in disturbed areas. The vegetation of the region is extremely fragile and, once disturbed, is difficult to reestablished. Many oversteepened slopes or disturbed areas have not revegetated or restabilized in more than 20 years. Grasses introduced for erosion control, for example, may require repeated fertilization in order to survive. Native plant species, while naturally adapted to the climate and soil conditions of the region, are slow growing, difficult to propagate, and do not provide sufficient ground cover in many instances.

1. Northstar-At-Tahoe

Northstar is ideal as a project site. Knowledge gained from studying the development and its water quality impact should be readily transferable to planning and construction activities in other critical areas with similar soils. As a result of thorough planning and careful construction practices, there were only a few, relatively minor problem areas remaining after construction of the initial phases of the development.

EROSION CONTROL PROJECT SITE LOCATIONS


NORTHSTAR
RUBICON PROPERTIES
LAKE TAHOE
STATE OF CALIFORNIA
OREGON
NEVADA
ARIZONA
MEXICO
Hobart Mills
TAHOE N.F.
BOCA HILL
PROSSER HILL
Truckee
DONNER MEM SŁ PARK
BALD MTN
Truckee-Tahoe
NEVADA CO
PLACER CO
MARTIS PEAK
Lookout tower
BROCKWAY SUMMIT
MT PLUTO 8617
BIG CHIEF
Carnelian Bay
MT WATSON
Tahoe Vista
Kings Beach
Brockway
CALIFORNIA
NEVADA
WASHOE COUNTY
CARSON CITY
DOUGLAS COUNTY
SQUAW VALLEY STATE REC AREA
WARD PEAK 8637
SCOTT PK
Lake Forest
Tahoe City
Sunnyside
STANFORD ROCK
TWIN PKS
Tahoe Pines
Homewood 6229
BARKER PK
Barker Pass
Chambers Lodge
Tahoma
PLACER COUNTY
EL DORADO COUNTY
Meeks Bay
SUGAR PINE PT ST PARK
D L BLISS STATE PARK
CAMP RICHARDSON 9 MI
39°00'
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0
5
SCALE

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STATE WATER RESOURCES CONTROL BOARD

EROSION CONTROL PROJECT SITES

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY	FIGURE NUMBER I-1

Northstar is located on a 1,036 hectare (2,560 acres) tract in the West Martis Creek watershed tributary to the Lower Truckee River as shown in Figure I-2. The elevation of the development varies from 1,775 meters (5,823 feet) at the north end of the tract to 2,625 meters (8,612 feet) at Mt. Pluto to the south. There is a ski area with six double chair lifts and 115 hectares (284 acres) of cleared ski runs in the upper elevations of the watershed. Residential-commercial complexes are in the middle elevations with an 18-hole golf course at the lower elevations.

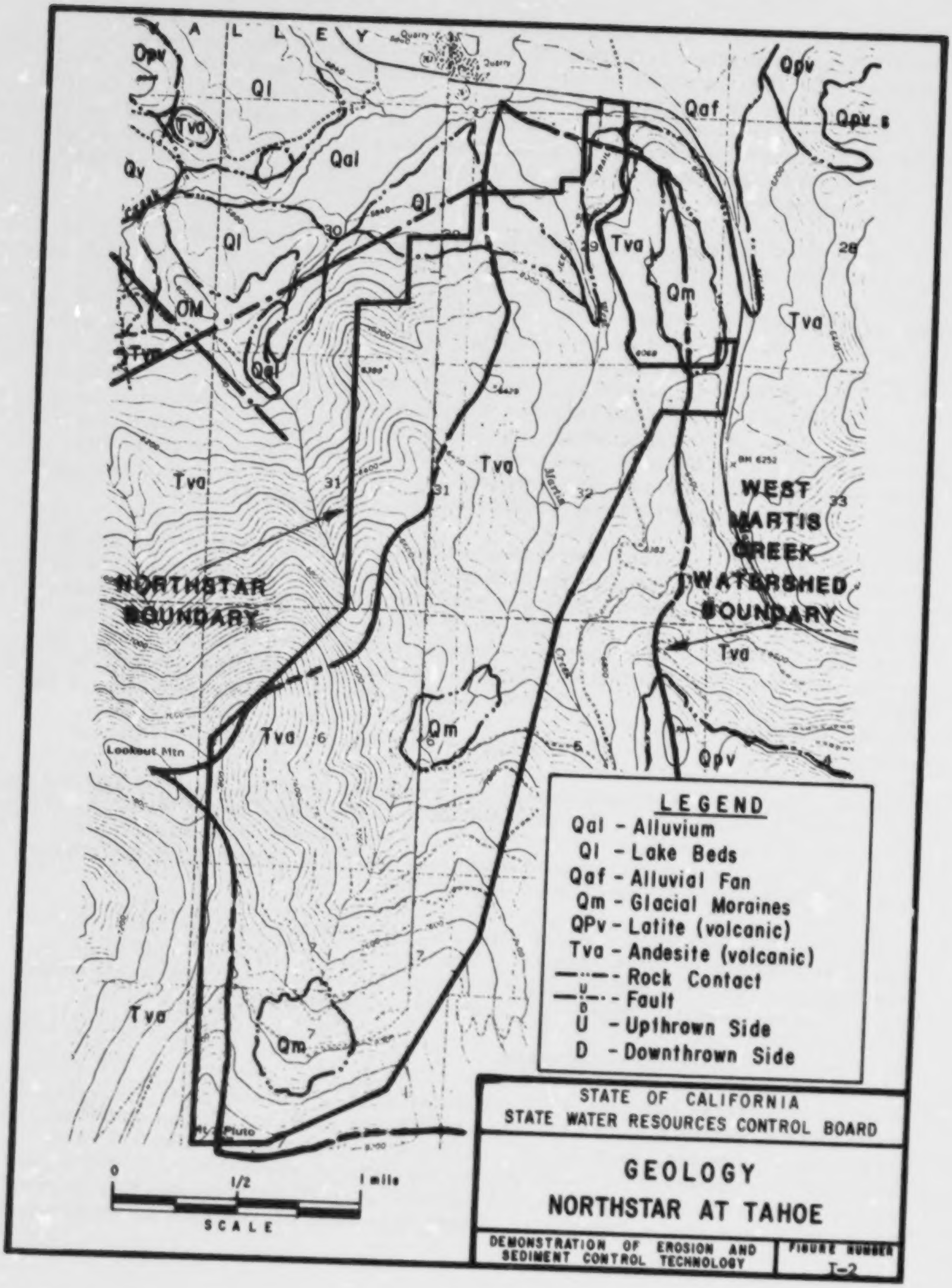
The geology of Northstar and the West Martis Creek watershed is typical of the northern one-third of the Lake Tahoe Basin and Truckee River watersheds which are covered by extensive flows of volcanic rocks of Tertiary and Quaternary age (See Figure I-2). Source areas of the older volcanics are unknown but are believed to be near Mt. Pluto. Rock units of Tertiary age consist of volcanic mud flow breccias and flows of andesite and latite. The flows are extremely resistant to weathering and have only a thin layer of soil, while the mud flow breccias are less resistant to weathering and develop a deep soil. In general, the Northstar-at-Tahoe development was provided with a relatively stable environment of Tertiary andesite. The deep weathering in the mud flow portions provides a thick soil that supports good vegetation, is relatively stable, and relatively pervious.

The upper portions of the watershed are vegetated by a thick, mixed coniferous forest. Middle to low elevations are vegetated by coniferous forest with mixed sagebrush and manzanita. Mean annual precipitation is 80 centimeters. Much of the area was extensively logged as was most of the Tahoe Basin in the 1800's. Only moderate logging activity has been conducted in recent decades. The West Martis Creek watershed was recently subject to only selected logging with no clear cutting prior to the construction of the Northstar development. The only other significant predevelopment human impact within the West Martis Creek watershed was the presence of sheep herders at the lower elevation. Although this activity probably had considerable impact on the open meadow and sagebrush lands, remaining impacts appear to be negligible. The only evidence indicating the one-time presence of sheep herders are a few structures and extensive irrigation canals in the low lands that used to spread the flow from West Martis Creek over a wide area to support range vegetation.

A complete discussion of the planning and construction methods that went into the development of Northstar is included in Sections III through V of this report. Section VII includes a discussion of the sediment and erosion related water quality impact of the Northstar development.

2. Rubicon Properties Subdivision

Rubicon Properties has been in a continual state of residential lot expansion and growth since 1945. In 1960 the final upper portions of the subdivision were added. However, even in 1977 only about 50 percent of the 632 lots are fully developed. The development runs from an elevation of 1,898 meters at the shore of Lake Tahoe to 2,180 meters. Magnificent views of Lake Tahoe are a principle reason for the continued expansion of the Rubicon Properties.



VALLEY
Quarry
Qpv
Ql
Tva
Qal
Qv
Qaf
Qpv
Qm
OM
Tvm
28
29
30
31
32
33
6
7
5
4
Trail
Martis
Creek
BM 6252
NORTHSTAR BOUNDARY
WEST MARTIS CREEK WATERSHED BOUNDARY
Lookout Mtn
Mt. Pluto
LEGEND
Qal - Alluvium
Ql - Lake Beds
Qaf - Alluvial Fan
Qm - Glacial Moraines
QPv - Latite (volcanic)
Tva - Andesite (volcanic)
Rock Contact
Fault
U - Upthrown Side
D - Downthrown Side
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1/2
1 mile
SCALE

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GEOLOGY
NORTHSTAR AT TAHOE

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER I-2

Lonely Gulch Creek which flows through the development, drains a 2.75 square kilometer watershed reaching to the top of Rubicon Peak at an elevation of 2,799 meters.

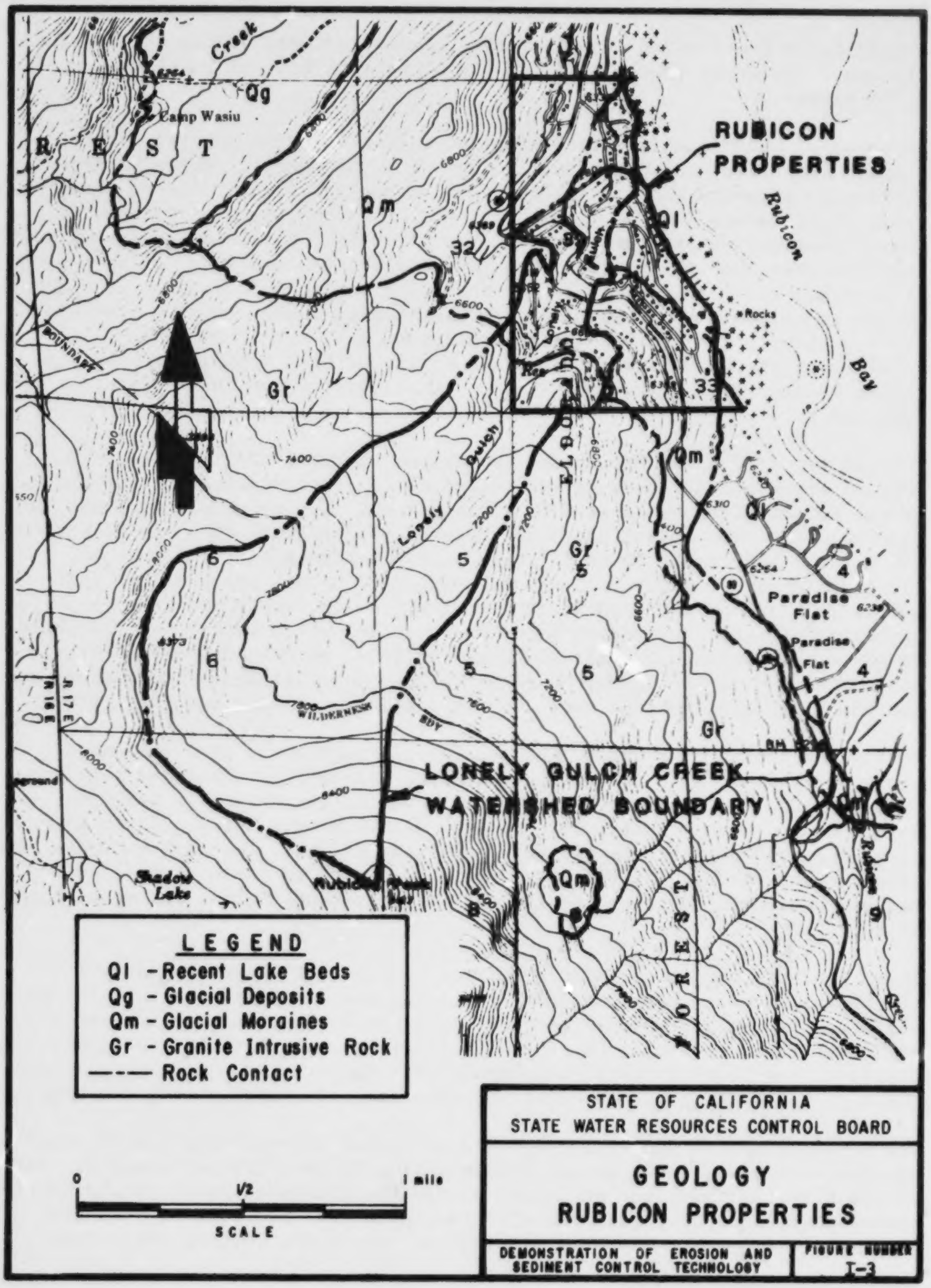
In terms of water quality protection and degree of environmental impact, Rubicon Properties is diametrically opposed to Northstar. Where Northstar's developers expended significant effort to construct a well planned development, the relative lack of planning at Rubicon Properties is obvious. Where construction practices used at Northstar were designed to have minimum environmental impact, Rubicon Properties was constructed with environmental disregard. Where the developers of Northstar continue to exhibit an ongoing desire to maintain a minimal environmental impact and to correct remaining minor problems, Rubicon Properties developers have long since sold all interest in the subdivision and may in no way be held accountable for the impact Rubicon Properties is having on water quality and the environment of Lake Tahoe.

The geology of Rubicon Properties is typical of the conditions found in much of the granitic southern two-thirds of the Tahoe Basin. The bedrock of the Rubicon Properties area is granodiorite. The principal minerals in this rock are: (1) quartz 15 to 32 percent, (2) plagioclase 43 to 55 percent, (3) potassium feldspar 10 to 20 percent, (4) hornblende 1 to 8 percent, (5) biotite -6 to 15 percent, and (6) augite -0 to 0.3 percent. In this subalpine climate, the granodiorite weathers quite deeply and is subject to both wind erosion and erosion from falling water where exposed and not held in place by vegetation. Variations in the level of Lake Tahoe in past millenia have led to the formation of lake shore deposits above the present shoreline of Lake Tahoe as shown on the attached geologic map (Figure I-3).

During the Pleistocene epoch, huge valley glaciers moved down the canyons along the western side of the Lake scouring away all of the loose rock and building great piles of morainal debris. During the period of maximum development, these glaciers were as much as 300 meters thick and, in some areas, covered all but the hightest peaks and ridges. The record of the advances and retreats of the glaciers is preserved in these glacial sediments. Four main advances are known to be represented along the west shore of the Lake.

These glaciers were especially important because they scoured away all of the weathered rock in the Rubicon Properties and exposed fresh rock at the surface. Granodiorite disintegrates along the boundaries between mineral grains so that, although the grains still fit together in their original position, the mass is loose, incoherent, and subject to considerable erosion. The sand and silt, products of rock weathering, are carried into the Lake.

The majority of the Lonely Gulch Creek watershed is vegetated with a mixed coniferous forest. Mean annual precipitation is over 100 centimeters. Very little human activity was conducted within the watershed prior to the development of Rubicon Properties subdivision, with the exception of extensive logging which occurred in the late 1800's. Since the logging activities


Creek
Qg
Camp Wasiu
R E S T
RUBICON PROPERTIES
Rubicon Bay
Qm
Ql
32
33
Rocks
Gr
BOUNDARY
Lonely Gulch
EL DORADO
5
6
4
Paradise Flat
R 16 E
R 17 E
WILDERNESS BDY
LONELY GULCH CREEK WATERSHED BOUNDARY
Shadow Lake
Rubicon Peak
FOREST
9
LEGEND
Ql - Recent Lake Beds
Qg - Glacial Deposits
Qm - Glacial Moraines
Gr - Granite Intrusive Rock
- - - Rock Contact
0
1/2
1 mile
SCALE

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GEOLOGY
RUBICON PROPERTIES

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER I-3

were conducted, the Lonely Gulch Creek watershed had an ample opportunity to return to relatively stable preimpact conditions, prior to the construction of Rubicon Properties subdivision.

A complete discussion of the Rubicon Properties development is included in Section VI of this report. Section VII discusses the erosion and sediment related impacts of Rubicon Properties.

B. Demonstration of Erosion and Sediment Control Technology

In addition to documenting the water quality impacts of the Northstar and Rubicon Properties developments, major emphasis of this erosion control project has been placed on the implementation and demonstration of a wide variety of erosion control techniques. At Northstar, the demonstration of specific, in-place erosion control techniques was confined to the few remaining erosion problem areas within the development. A total of 50 plots was established at Northstar to demonstrate the effectiveness of a variety of slope and disturbed area revegetation and stabilization techniques. At Rubicon Properties, the erosion problems were not confined to a few isolated areas but rather encompassed the entire development. Erosion control demonstration work within Rubicon Properties was confined to the worst portions within the Lonely Gulch Creek watershed. It is anticipated that the effectiveness of the demonstrated techniques will be reflected by the improved water quality of Lonely Gulch Creek. Over 200 separate plots have been established within Rubicon Properties to demonstrate a variety of erosion control vegetation and stabilization techniques, either singly or in combination. Section VIII describes the wide variety of erosion control techniques which were conducted as part of this project. Appendix A describes procedures for the propagation of plants suitable for the revegetation of disturbed slopes in the Lake Tahoe region of California. Appendix B describes the specific plot locations at the two project sites where the erosion control techniques were demonstrated.

SECTION II

CONCLUSIONS AND RECOMMENDATIONS

1. Poorly planned, constructed, and maintained developments can result in extremely severe erosion and sedimentation rates, which in turn can have a massive impact upon surface water quality. This is exemplified by high levels of suspended sediment, turbidity, sediment deposition, and the destruction of aquatic life in streams whose watersheds contain such improper developments.

2. Adequate technology exists to insure that properly planned, constructed, and maintained developments that cause land disturbances will have a minimum, if not negligible, impact upon surface water quality from the standpoint of erosion and sediment.

3. In insuring that future construction of residential and recreational developments results in a minimum amount of erosion and sediment discharge to surface waters, the planning concepts of (1) restricting land uses to suitable sites which are capable of supporting the particular use, (2) minimizing disturbed land surfaces, particularly road cuts and fills, and (3) prohibiting land disturbances from encroaching upon stream environment zones, are of premier importance. At a minimum, thorough evaluation of a proposed development project site should include detailed analysis of the natural vegetation types, vegetation density, geology and soils, drainage, and slope. Erosion and sediment control concepts and requirements identified in the predevelopment planning stages must be fully recognized and adhered to during and after actual construction to minimize potential problems.

4. Adequate technology exists to substantially reduce the water quality impact of poorly planned, constructed, and maintained developments of the past. However, reducing erosion and sediment production rates to predevelopment levels would be extremely expensive and difficult in some cases.

5. Adequate regulatory and enforcement tools exist in the State of California, as embodied in the laws of the State when implemented by regulatory agencies, to insure that erosion and sediment control problems are prevented in the future and that past problems are corrected.

6. The lack of sufficient funds to correct erosion and sediment control problems generated by past activities (prior to the advent of sufficient environmental controls) is the primary roadblock to the adequate

control of erosion and sedimentation resulting from construction activities.

7. One of the erosion control demonstration project sites, Northstar-At-Tahoe, is a well planned, constructed, and maintained year-round residential-recreational development complex. Potentially adverse environmental impacts of the development were mitigated by careful planning, government regulations, and the implementation of proper control measures. The few remaining isolated sediment and erosion problems within the development are primarily the result of departures from the strict construction and management controls outlined in the planning process.

8. The construction of Northstar-At-Tahoe has resulted in less than 100 percent increase in sediment yield to the West Martis Creek watershed above very low background levels. The effect of this increase on the monitored aquatic life of West Martis Creek has been negligible. The sources of this increased sediment yield include a few isolated instances of oversteepened slopes, unrevegetated terrain, uncontrolled drainages, and heavily travelled dirt roadways which involve less than 0.3 percent of the total development. Because of their isolated and limited nature, the application of additional erosion control methods should further reduce sediment loads discharged from the Northstar development.

9. The cost of extensive planning activities and erosion control measures implemented by the developers of Northstar-At-Tahoe is currently estimated to be less than $400 per developed unit (condominiums or residential lots). With ultimate planned buildout, the cost per developed unit at Northstar is estimated to be reduced to approximately $220. Thus, the actual unit cost of effective preplanned erosion control at Northstar is nominal.

10. The other erosion control demonstration project site, Rubicon Properties, is a classic example of the extremely poor development practices which have been conducted within the Lake Tahoe Basin in the past. From the standpoints of erosion control, drainage control, water supply, roadway construction, land capabilities, esthetic appeal, snow removal, and general maintenance, the upper portion of Rubicon Properties is exemplary of a poorly planned, constructed, and maintained development.

11. The development and construction of the upper portions of the Rubicon Properties subdivision has resulted in an estimated 10,600 percent increase above the natural background sediment yield from the area prior to the erosion control project. Evidence exists that indicates erosion rates may have been as high as 100,000 percent above natural background rates immediately after construction of the subdivision in the early 1960's. The main sources of the eroded material are oversteepened slopes, unvegetated terrain, uncontrolled drainages, and abandoned dirt roads which occupy 13 percent of the land surface within the upper portions of Rubicon Properties subdivision. The impact on the monitored aquatic life of Lonely Gulch Creek has been significant. Monitored

species in the stream have been reduced in numbers by an average of 70 percent below the development. Peak instances of species reduction have reached levels of over 99 percent. Species diversities in Lonely Gulch Creek below the development have also been adversely affected.

12. Had El Dorado County adequately recognized the requirements of their own subdivision ordinance in the late 1950's, it is unlikely that the upper portions of Rubicon Properties would have been constructed. For example, the county ordinance required that all cut and fill slopes adjacent to roadways accepted by the county must be included in the legal right-of-way. Had this been the case at Rubicon Properties, considerably less land area would have been available for subdivision into parcels (up to 13 percent less land). In addition, if the subdivision had been constructed in conformance with county ordinances, the main problem areas would have remained in single ownership, considerably facilitating the solution of the problem.

13. One of the major obstacles to effective erosion control at Rubicon Properties was the necessity to obtain permission from each of the 129 individual landowners to gain access to their property for purposes of erosion control. At Northstar, where the majority of the remaining problem sites are still owned by the original developer, problem correction, when necessary, is greatly facilitated.

14. The cost of constructing adequate erosion control facilities at Rubicon Properties subdivision, such as those implemented as part of the erosion control demonstration project, could be as high as $2,000 per existing residential lot if conducted on a commercial basis. The additional cost of effective drainage control and sediment catchment facilities would add an estimated $1,000 per residential lot. Furthermore, the continuation of residential building construction within the project site will increase the impervious surface coverage from 16 to 36 percent within that portion of Rubicon Properties at full build-out. Based upon land use capability, ideal impervious coverage should not exceed one percent. Even with the implementation of extensive erosion control techniques, the increased runoff from impervious surfaces will create additional erosion problems which will be even more difficult to control.

15. The implementation of disturbed slope stabilization techniques to achieve control of erosion problems within Rubicon Properties is expected to reduce the previously excessive sediment yield rates by about 80 to 90 percent. This level of treatment is significant and is roughly analogous to "secondary treatment" for suspended solids removal as in a sewage treatment plant. At Rubicon Properties, however, this "secondary treatment" would result in erosion and sedimentation rates which are still approximately 1,000 percent above natural background levels. The addition of settling basins and sediment collection facilities at Rubicon Properties would probably further reduce the sediment yield rates by an additional 90 percent, which would be roughly analogous to "tertiary treatment" of suspended solids removal in a sewage treatment plant. At such treatment level, sediment yield rates at Rubicon Properties would

only be 100 percent above natural background levels and would be similar to the low sediment yield rates generated by the Northstar development.

16. The cost to the county for eroded sediment cleanup and maintenance within the upper portions of Rubicon Properties subdivision, prior to construction of effective erosion control facilities, is estimated to have been approximately $11,500 per year. The cost to the county to conduct a project similar to the Demonstration Project at Rubicon Properties would be $120,000. Based on the following assumptions, the cost of effective erosion control would be amortized over a period of 12.5 years, and the additional cost of complete drainage control and sediment collection facilities would be amortized over a 20 year period:

    1) Negligible erosion and sediment control maintenance would be required after such a project.
    2) Only maintenance cost savings are ascribed to the cost of effective erosion control, with no costs allocated to environmental protection and enhancement.
    3) The long-term increased maintenance cost rate is 6 percent (27 year ENR construction index since 1950).
    4) Money may be borrowed at 8 percent interest.

17. Erosion control measures, which may be applied to various erosion problems, are very site specific. Depending upon soil type, slope angle, slope length, seepage areas, exposure, rockiness, elevation, and various control measures, either singly or in combination, may achieve the most cost-effective level of erosion control. Site investigations must be made prior to the implementation and cost estimating of specific erosion control projects.

18. The estimated commercial cost of erosion control at Rubicon Properties was approximately $75,000 per hectare of disturbed slope surface. Techniques ranged from simple seeding and mulch application with an estimated commercial cost of less than $3,000 per hectare to extensive improvements, including retaining walls, willow wattling, plantings, seedings, and mulching at a maximum estimated commercial erosion control cost of over $200,000 per hectare of disturbed slope surface. The cost of individual revegetation techniques ranged from $3,000 to $20,000 per hectare. In most instances, considerable additional funds were required for mechanical slope stabilization prior to revegetation. As eroding slopes become steeper and longer, the vegetative portion of effective erosion control represents only a small portion of the total cost.

19. The use of straw mulch with a chemical or mechanical tackifier is among the most cost-effective of erosion control and revegetation techniques which were demonstrated at the project site. The establishment of vegetative cover by using a straw mulch does as well, or better, than other demonstrated techniques, some of which are considerably more expensive.

20. The technique of contour wattling should receive greater use as a means to mechanically stabilize and revegetate oversteepened slopes. The

growth of other types of seeded or planted vegetation is noticeably higher on slopes which have received a contour wattling treatment.

21. The use of rooted seedlings of native and, in some cases, exotic shrubs is an effective means of revegetating and stabilizing disturbed areas but is not feasible in many instances due to prohibitively high plant production costs. Currently, commercial production costs of large quantities of many types of rooted shrub seedlings range from $.50 to $1.00 per plant. Newer, more efficient propagation techniques used as part of this erosion control project may reduce shrub production costs to less than $.10 per plant.

22. Effective erosion control is extremely labor intensive. For example, 82 percent of the cost of commerical willow wattling installation is labor cost. Erosion control costs for large projects may be substantially reduced by employing conservation corps workers to perform unskilled tasks. Theoretically, overall costs may be reduced as much as 45 percent. The actual average cost of erosion control at Rubicon Properties, using conservation corps workers where possible, was $58,200 per hectare of disturbed slope surface, which is a 33 percent reduction in the estimated commercial cost of such an operation.

23. Strict adherence to certain existing county ordinances exacerbates erosion problems and leads to higher erosion control costs. For example, the requirement that paved road surfaces must be maintained with at least a 7.9 meter width more than quadrupled the cost of erosion control within certain portions of Rubicon Properties. Maintenance of a 7.9 meter road width led to the construction of expensive gabion retaining walls ($60-$180 per meter) where a narrower roadway would accommodate curbs, gutters, and benches at the toe of eroding cut slopes ($15 per meter). The total cost to the county to conduct an erosion control project similar to the Rubicon Properties project would be reduced by 25 percent if the need for retaining wall structures were eliminated.

24. Certain state, county, and utility district maintenance practices increase the severity of existing erosion problems. Among them are:

    - The practice of removing accumulated sediments from the toe of eroding slopes, thereby undercutting the slope, leads to further destabilization. Better practice would be to move existing drainage further away from the toe of the slope or to construct retaining structures at the toe of eroding slopes.
    - Washing culverts and drains clogged by eroded sediments increases the rate of downslope sediment transport. A better procedure would include dry boring or reaming to remove sediments coupled with proper disposal of the waste earthen material.
    - Insufficient snow stakes can cause increased damage to curbs, dikes, gutters, culverts, retaining walls, and slope toe benches by snow removal equipment.

- Improper disposal of waste earthen material, such as "over-the-bank" practices, increases sediment transport and hinders the proper establishment of slope stabilization measures.
- The application of road sand to facilitate winter travel, without providing for the adequate removal of accumulated sand, further increases the rate at which sediments are discharged to surface waters.
- Cleaning roadways of accumulated sediments by means of water flushing or simple brushing generally increases the rate of sediment discharge to surface waters. A better method is the use of a vacuum sweeper to clean and properly collect and dispose of the accumulated sediments and waste earthen materials.

SECTION III

PREDEVELOPMENT PLANNING AND PRELIMINARY SITE ANALYSIS AT NORTHSTAR

A. Introduction

Northstar-At-Tahoe was planned as an all-year recreation and resort community utilizing portions (1,036 hectares) of a privately-owned 10,500 hectare tract north of Lake Tahoe in California. Northstar's facilities include a major ski complex, summer recreational facilities, condominium residences, a limited number of lot parcels for single-family dwellings, an eighteen hole golf course, and a commercial village center.

In planning Northstar-At-Tahoe, the developers were guided by a philosophy which recognized the unique qualities and ecological processes of the landscape and considered them to be the primary determinants of the proper form of development. Considerable effort was made in the planning process to insure that the Northstar-At-Tahoe Development Plan would not violate the landscape, but rather work with it to form a "harmonious relationship between man and environment." (4)

The four cornerstones of planning that were used in the preliminary site and feasibility analysis at Northstar were the following (4)

1. Physical analysis
2. Market analysis
3. Profitability
4. Government coordination

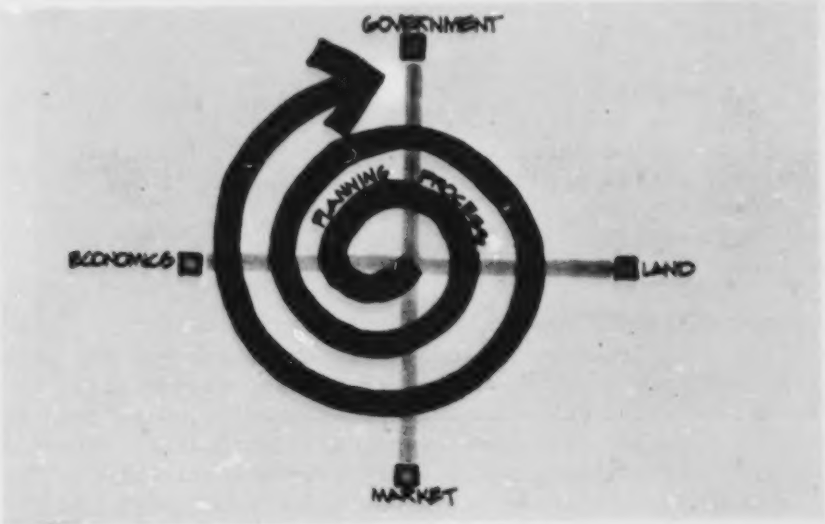
The interrelationship of the four cornerstones of the planning process used in the development of Northstar is depicted in Figure III-1. The evolution of thorough planning, as exemplified by Northstar-At-Tahoe, is not a straight-line process but a cyclical one by which the developers were able to continually reevaluate all criteria as the plan evolved to determine their validity and feasibility and, thus, to define the directives leading to succeeding development stages. The continual reevaluation of the four cornerstones of planning led to the creation of an extensive development which minimized adverse environmental impacts and produced a marketable product.

The primary cornerstone of Northstar planning was the comprehensive physical analysis of the original 10,500 hectare tract. Preliminary investigations were conducted to identify which major aspects of the site's environment, including geology, soils, slopes, drainage, access, and what types of development could best serve (and be served) by the natural character of the land.

After identifying the site's capabilities and limitations, the planning turned to a determination of the public needs and interests for the types of amenities, activities, and projected land capabilities of the site. A market study was conducted to determine what the interests and needs of the public were for potential types of development activities such as:

1. Condominiums
2. Residential lots
3. Ski area development
4. Natural terrain
5. Other recreational activities

As the projected need and interests of the public were identified by the market study, the profitability of providing the various amenities were examined.



SOURCE: EDAW for Trimont Land Co.

Figure III-1 - The four cornerstones of the Planning Process Identified in the Development of Northstar

The fourth and last of the basic cornerstones of planning used in developing the Northstar project was close coordination with local, regional, and state governmental agencies. During the late 1960's and early 1970's, when comprehensive environmental legislation and ordinances were first emerging, the Northstar developers worked closely and cooperatively with all levels of government.

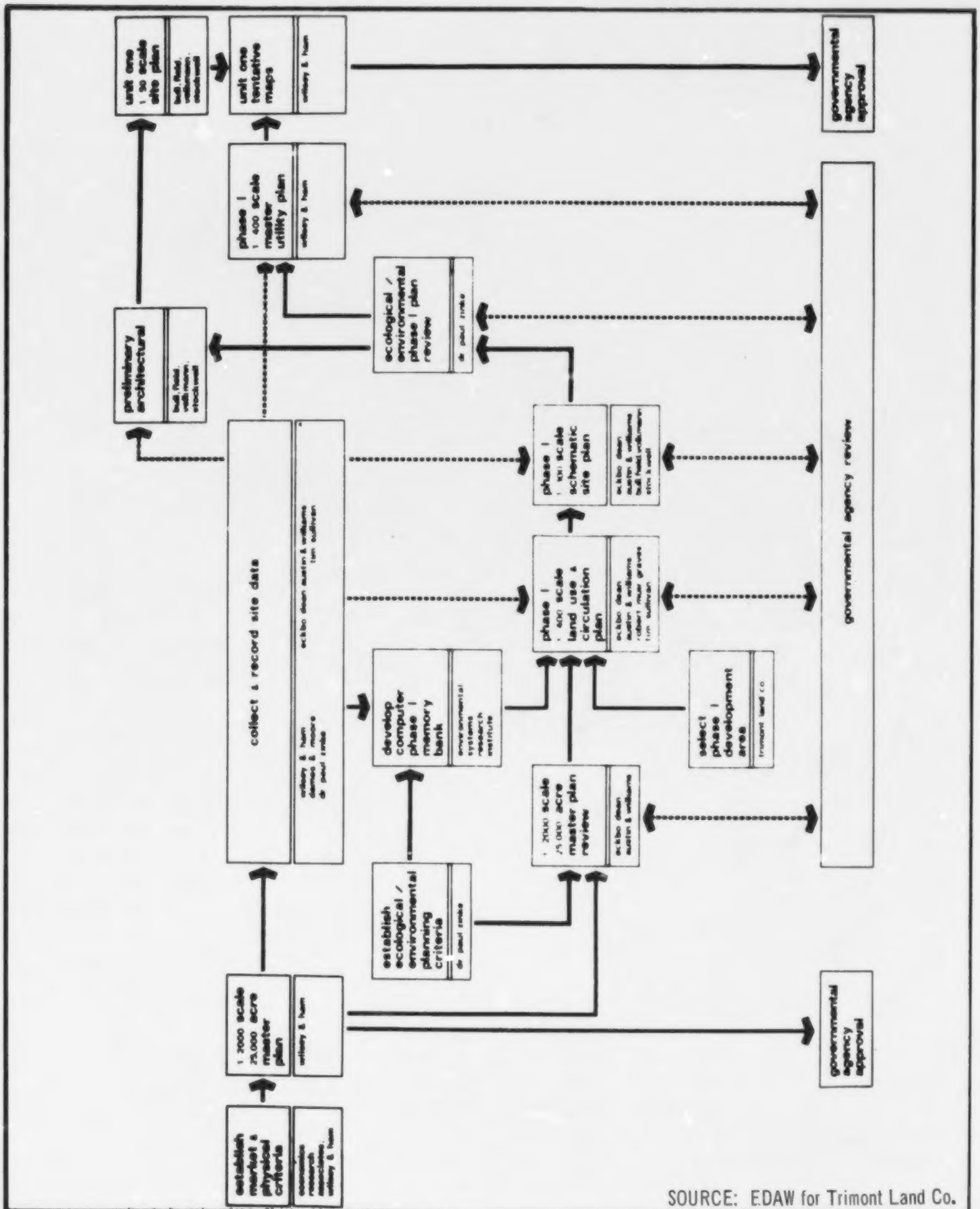
Strict adherence to these planning criteria also provided protection to local government. In many instances, local government has been financially burdened by ill-fated developments, half-finished subdivisions, vacant lots, scarred land, and maintenance headaches. While Northstar-At-Tahoe is relatively free of these problems, Rubicon Properties, the second erosion control demonstration project site, is a perfect example of the wide variety of burdens which are placed on local government and on the environment as a result of inadequate planning. The lack of adequate planning at Rubicon Properties will be thoroughly discussed in a subsequent section of this report (see Section V).

B. Planning Team Identification

In order to adequately address the four cornerstones of planning, a multidisciplinary team of consultants was retained by the developer. The various areas of expertise included the following:

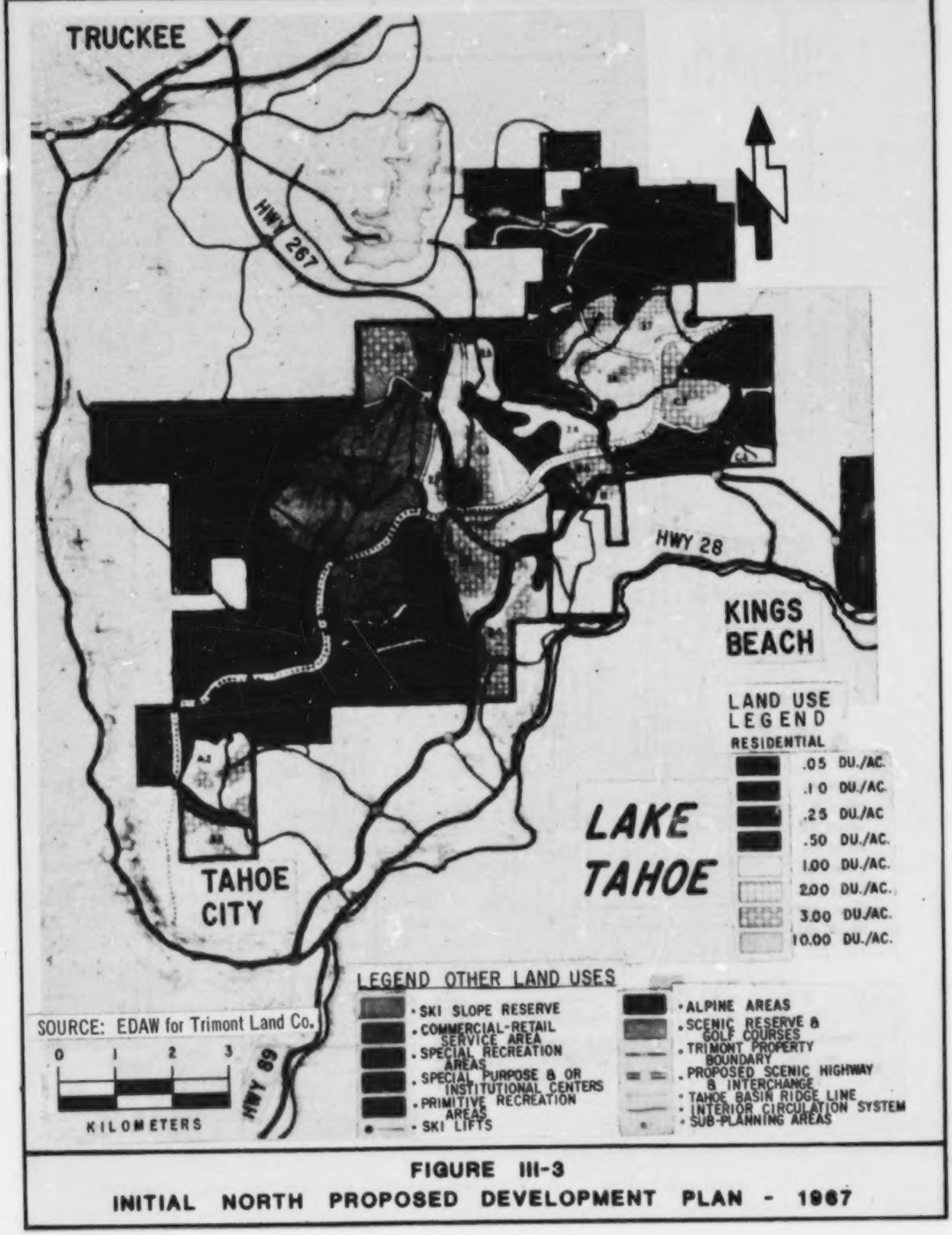
1. Economics-marketing
2. Planning
3. Ecology
4. Soils-geology
5. Planning computer
6. Ski-hill planning
7. Golf course planning
8. Architecture
9. Engineering
10. Legal

A flow chart depicting the sequences of responsibilities is shown in Figure III-2. Initially, the consulting engineers and the economics-marketing consultants proposed the preliminary master plan shown in Figure III-3 encompassing the entire 10,500 hectare tract. This initial planning was based solely upon an initial market analysis, existing site information, and cursory site investigation. The initial proposed master plan was heavily dependent upon the obvious physical features of the land. From this point on, the various components of the master plan received intense scrutiny and revision. The primary responsibility of the planning consultants was to determine the feasibility of the initial proposed development plan as determined by environmental considerations.


establish market & physical criteria
economic research associates, wilsey & ham
1:2000 scale 25,000 acre master plan
wilsey & ham
governmental agency approval
collect & record site data
wilsey & ham, dames & moore, dr paul zinke
eckbo dean austin & williams, tom sullivan
establish ecological / environmental planning criteria
dr paul zinke
develop computer phase I memory bank
environmental systems research institute
1:2000 scale 25,000 acre master plan review
eckbo dean austin & williams
select phase I development area
trimont land co
phase I 1:400 scale land use & circulation plan
eckbo dean austin & williams, robert muir graves, tom sullivan
phase I 1:100 scale schematic site plan
eckbo dean austin & williams, hall field williams stockwell
governmental agency review
preliminary architectural
hall field williams stockwell
ecological / environmental phase I plan review
dr paul zinke
phase I 1:400 scale master utility plan
wilsey & ham
unit one 1:50 scale site plan
hall field williams stockwell
unit one tentative maps
wilsey & ham
governmental agency approval

SOURCE: EDAW for Trimont Land Co.

FIGURE III-2. NORTHSTAR PLANNING FLOW CHART


TRUCKEE
HWY 267
HWY 28
KINGS BEACH
LAKE TAHOE
TAHOE CITY
HWY 89
LAND USE LEGEND
RESIDENTIAL
.05 DU./AC.
.10 DU./AC.
.25 DU./AC
.50 DU./AC.
1.00 DU./AC.
2.00 DU./AC.
3.00 DU./AC.
10.00 DU./AC.
LEGEND OTHER LAND USES
• SKI SLOPE RESERVE
• COMMERCIAL-RETAIL SERVICE AREA
• SPECIAL RECREATION AREAS
• SPECIAL PURPOSE & OR INSTITUTIONAL CENTERS
• PRIMITIVE RECREATION AREAS
• SKI LIFTS
• ALPINE AREAS
• SCENIC RESERVE & GOLF COURSES
• TRIMONT PROPERTY BOUNDARY
• PROPOSED SCENIC HIGHWAY & INTERCHANGE
• TAHOE BASIN RIDGE LINE
• INTERIOR CIRCULATION SYSTEM
• SUB-PLANNING AREAS
0
1
2
3
KILOMETERS

SOURCE: EDAW for Trimont Land Co.

FIGURE III-3

INITIAL NORTH PROPOSED DEVELOPMENT PLAN - 1967

C. Evaluation of the Prime Physical Features and Conflict Analysis (5)

The critique by the planning consultants of the initial proposed development plan was based upon the degree to which the ecological integrity of the site would be affected by the proposed development.

The ecological studies were concerned with vegetation, soils, geology, and water balance of the property. A vegetation survey was made from aerial photographs of the property. This, in turn, was related to geologic and related soil types. Water balances for the property were determined from climatic data from weather stations adjacent to the Northstar property.

The complexities of the landscape were separated into individual components. Each ecological or landscape component was mapped at 1:24,000 scale. This information was evaluated according to its suitability for development. By overlaying the plan on each landscape consideration, the areas for which the proposed development conflicted with the ecological capability or which required specific considerations were identified. Potential conflicts were then summarized and identified on separate maps as primary and secondary conflicts. The composite of these conflicts indicated the areas of the plan, which should not be developed, and identified those areas which possessed the greatest development potential.

The ski area and base area of the development plan were studied in greater detail. This enabled more extensive analysis of the planning determinants, further enabling these determinants to influence specific site planning configurations.

The following analyses of the vegetation, soils, geology, and water balance were conducted in order to classify the information according to its suitability for development.

1. Vegetation

The landscape of the Northstar property is dominated by a range of vegetation zones from the lower elevations of Martis Valley to the higher slopes of Mt. Pluto. A large portion of the beauty the site derives from this vegetation and the environment of each development unit and lot depends upon the type of vegetation in which each unit is set.

- Broad Vegetation Zones:

  The vegetation was divided into major zones on the Northstar property by the planners. The lower elevations along west Martis Creek are in a Sagebrush and grass vegetation zone.

This is in the driest part of the original tract. Next, rising in elevation, one enters a Pine Forest-sagebrush zone, then a mixed Pine-Fir Forest, and Fir Forest along most of the higher elevation ridges. In addition, there are local or "azonal" vegetation types, such as aspen groves, meadows, willow thickets, mountain alder thickets, rockland, and fire types, such as brush fields and thickets of young tree regeneration.

- Vegetation Types

From the combination of these vegetation zones and the azonal types related to other variables, a mosaic of vegetation types result. This mosaic of vegetation types has an expression visually in age or size classes of trees, crown density of trees and shrubs, and on structural elements of vegetation. The following classification types were developed from aerial photographs of the Northstar property.

- Structural Class of Vegetation or Ground Cover Type

C	Conifer trees
H	Hardwood trees
S	Shrubs, i.e. manzanita or sagebrush
R	Rock
B	Bare Ground

- Age Class (based on size of crown) of Conifers

O	Old, greater than 75 years
Y	Young, less than 75 years
R	Recent regeneration, less than 15 years

- Density Classes of Crown Canopy (based on aerial photographs)

  80 - 100%
  60 - 80%
  30 - 60%
  5 - 30%
  less than 5%

The structural elements of each vegetation type were placed in the denominator of a fractional symbol, while the age class and two density symbols (one for conifer density and the other for total woody vegetation density) were placed in the numerator. Two examples follow:

$$\frac{OY22}{CB}$$

This states that the cover is conifer vegetation (C) with some bare ground (B); there are two age classes present, old (O), and young (Y); and that the old age class is most abundant (OY). The first density figure indicates that total conifer density is 60 to 80 percent crown cover (2), and that this makes up all the woody vegetation density 60 to 80 percent (2).

$$\frac{51}{S}$$

This indicates a cover type that is shrub (S), with less than 5 percent cover density (5), but 80 to 100 percent woody vegetation cover (1) made up of brush.

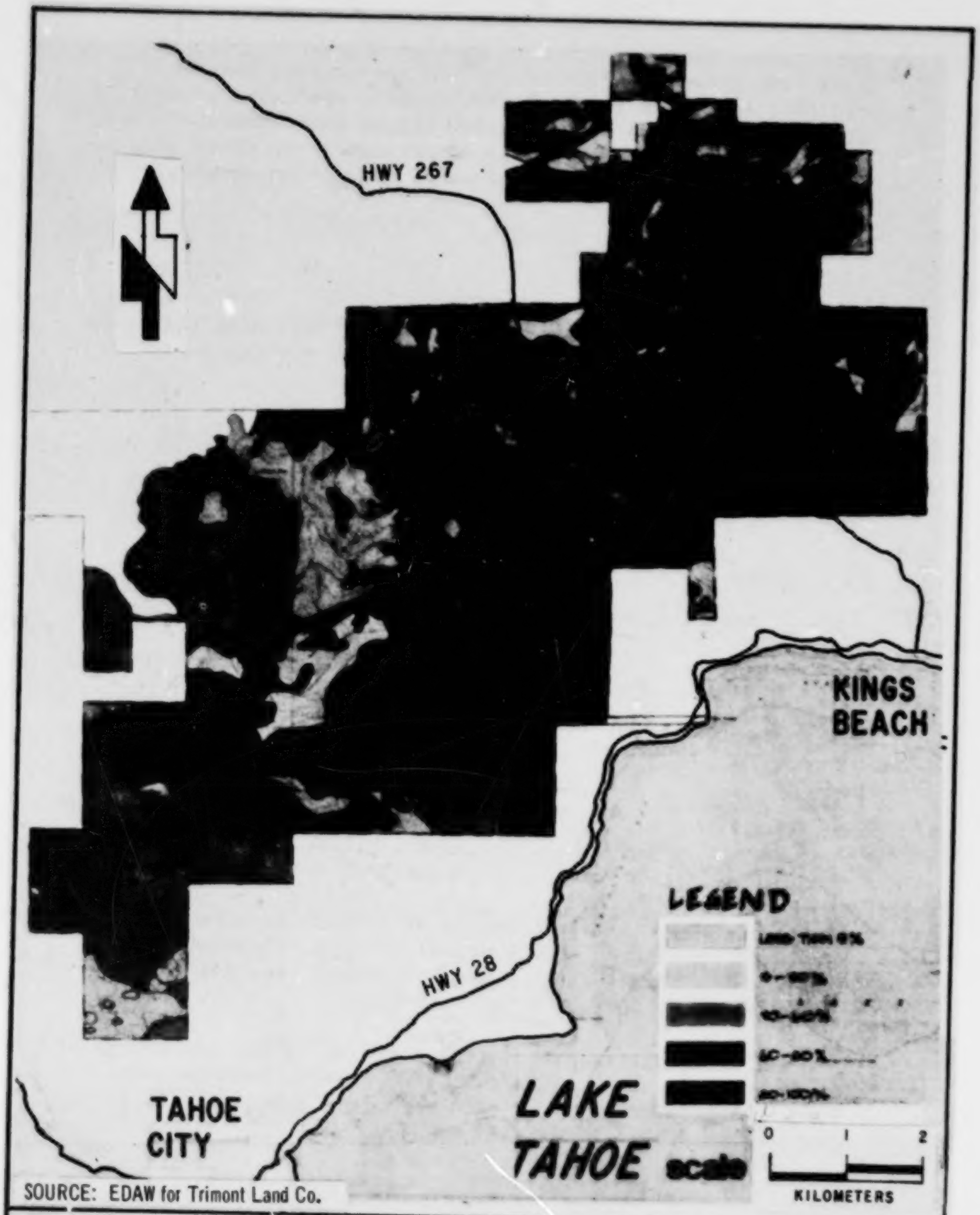
From this vegetation classification, it was possible to single out vegetation types and vegetation densities for specific consideration and evaluation as their suitability for development. Specific vegetation types are

•	Mixed Conifer	Ponderosa Pine, Jeffrey Pine, Ledgepole Pine, White Fir, Red Fir, Incense Cedar
•	Pine Fir	Ponderosa Pine, Jeffrey Pine, White Fir, Red Fir
•	Pine - Sagebrush	Jeffrey Pine, Ponderosa Pine Sage
•	Various	Sagebrush - grass enclaves, Aspen, Willow, Mountain Alder, Manzanita, and meadow

Of these, only the last category of various species in small areas was considered highly sensitive to development impact. The Pine-Sagebrush category was considered less desirable than the others from a visual standpoint.

Vegetation density was measured according to the percentage of area covered by the vegetation crown as seen from the air. The vegetation density map developed from this analysis is depicted in Figure III-4.

•	Less than 5%	Primarily open space
•	5 - 30%	Desirable density for development


HWY 267
KINGS BEACH
LEGEND
LESS THAN 5%
5 – 30%
30–60%
60–80%
80–100%
HWY 28
TAHOE CITY
LAKE TAHOE
scale
0
1
2
KILOMETERS

SOURCE: EDAW for Trimont Land Co.

FIGURE III - 4

NORTHSTAR VEGETATION DENSITY ANALYSIS

30 - 60%	Acceptable for development since no more than 30 percent would necessarily be removed
60 - 80%	Minor development problems since more than 30 percent would be removed for intensive development and, therefore, the remaining vegetation becomes less stable
80 - 100%	Serious development problems since 50 to 60 percent would be removed with the potential to seriously affect the ecology of the remaining stand

2. Geology and Soils

All of the Northstar property is dominated by volcanic igneous rock, except for some glacial deposits and alluvial areas in Martis Creek Valley. The soils which are derived from the weathering of these rocks vary in depth and development in response to climate, nature of the bedding, and composition of the original rock. The higher elevation areas of the property are characterized by shallow stony soils. Such soils are not well suited for development.

The majority of the Northstar development area is composed of brown forest soils, 1 to 2 meters deep and moderately stony. These soils occur on the property generally above 1,950 meters elevation and below 2,300 meters. The drier portion of the property on the Martis Valley side is characterized by darker, heavier soils developed on the andesite rock. The extent of these soils can be related to the occurrence of sagebrush.

There are local areas of soils associated with poorly drained areas, such as springs and meadows which will be different from the other soil types. These meadows and seep area soils have high moisture storage capacities (30 centimeters to 60 centimeters), and also high nitrogen contents (approximately 9,000 to 11,000 kilograms per hectare to a depth of 1.25 meters). They are highly reactive and have a good capacity to absorb applied nutrient and organic matter without discharge to groundwater in deep seepage effluent.

3. Drainage

A water balance made by deducting expected losses from precipitation on the property. Supporting data was gathered from the records of the Central Sierra Snow Laboratory at Donner Summit and from the weather data at Truckee and Tahoe City. The analysis indicated that the streamflow from the area accounts only for about 60 percent of the total estimated yield. Thus, there must be considerable subsurface flow from the West Martis Creek Watershed. This is not unreasonable considering the nature of the igneous rock geology and the alluvial fill in the West Martis Creek drainage.

In addition to the water balance information, the following stream classification was prepared by the Northstar planners.

-	Intermittent Streams	Those with only seasonal flow
-	Perennial Streams	Small streams which flow throughout the year
-	Flood Plains	Streams with sufficient flow such that a 25 year flood must be provided for with an additional 15 meter easement

Predevelopment surface storm or snowmelt runoff from the area of the Northstar property was slight. The soils are very permeable and runoff coefficients are low. Some concentration of runoff did occur along skid trails and logging roads but, in general, did not exceed the infiltration capacities of the soils. However, it was acknowledged that there would be a change in the runoff regime following development, particularly as affected by impervious surfaces and changes in vegetation density.

The change in surface runoff patterns from the development area was assumed to be proportionate to the impervious area of roofs and road surfaces within each subwatershed. The location of these impervious areas relative to the infiltration capacities of intermingled land surfaces was a primary factor influencing development concentration and spacing.

The overall objective of the design of surface runoff regulation at Northstar was to contain runoff in channels or to infiltrate the water without erosion. The variation and location of small runoff surfaces necessitated the design of small drainage systems which would not overload the infiltration capacities of the soil nor the flow capacity of natural and artificial channels.

Particular attention was given to points of concentration, such as road cuts, road surfaces, roof surfaces, and disturbed soil areas. Once the runoff is concentrated into channels, additional provision for energy dissipation is necessary due to the increased flow rates. Concentration of runoff on newly disturbed soil surfaces, such as fill material, was recognized as a potentially serious problem.

4. Slope

Slope steepness is the most important single determinant for planning purposes, particularly from the standpoint of erosion control. Not only does the cost and, therefore, the feasibility of construction rise in direct proportion to the slope of the land but also consequent erosion and sliding are liable to prove costly, visually destructive, and detrimental to water quality.

Slope was categorized accordingly:

- 0 - 6% slope	This represented the maximum desired slope for roads under snow conditions
- 7 - 11%	This represented the maximum desired slope for roads under normal conditions without snow
- 12 - 15%	This represented the maximum slope which should typically be considered developable
- 16 - 25%	Under specific and exceptional circumstances, it may be possible to develop land in this category at very low densities
- Over 25%	Land in this category would not be developed under any circumstances

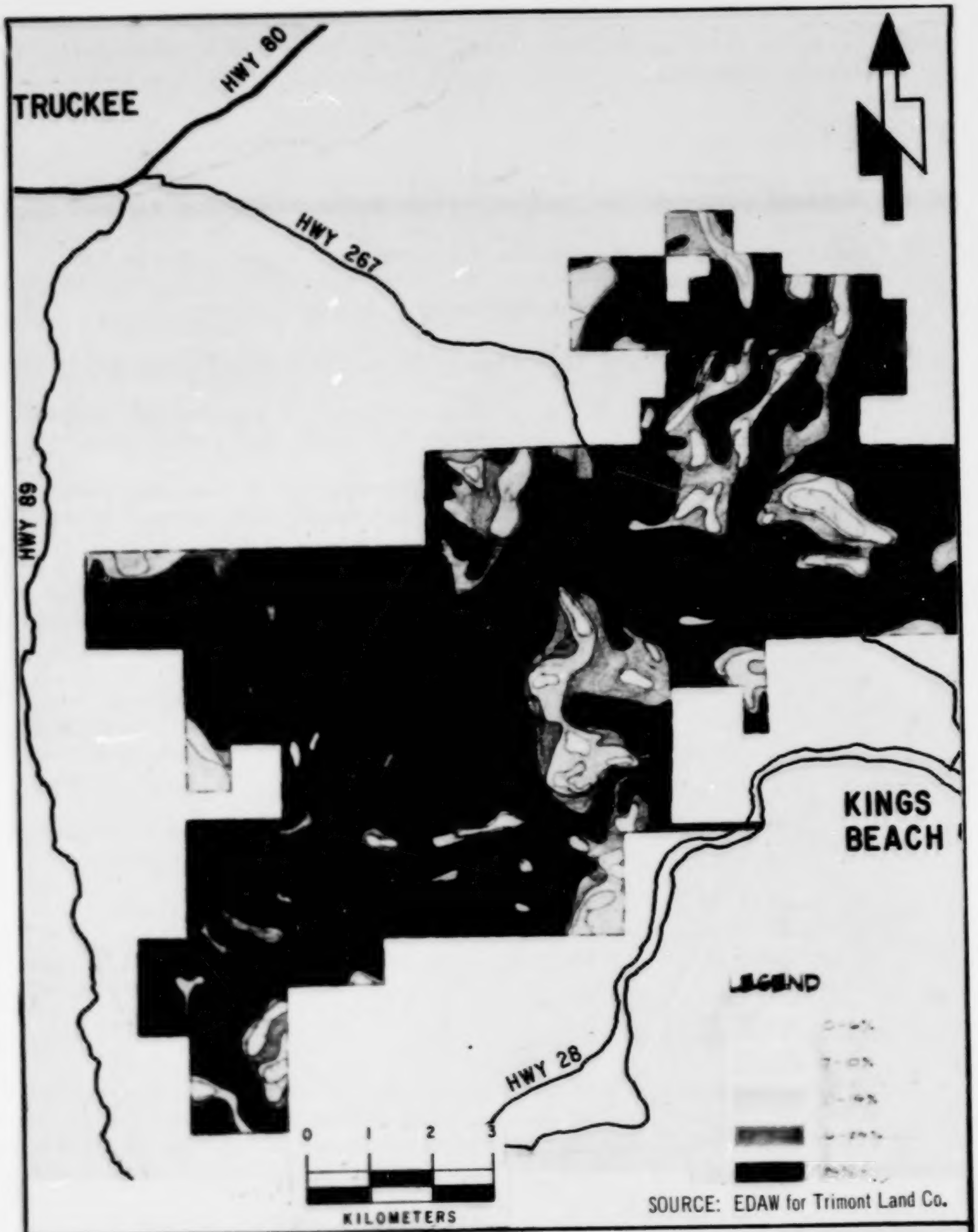
The results of the slope analysis are shown in Figure III-5. In Figure III-5, the darkest areas have slopes greater than 25 percent, while the lightest area is indicative of 0 to 6 percent slope.

5. Exposure and Snow Depth

From the existing record of snowfall in the area and with specific reference to the 1967/68 season, some general estimates of snow depth according to elevation for the site were made. Three major divisions were determined to exist

- Below 150 cm	Average annual snow depth
- 150 - 230 cm	Average annual snow depth
- Over 230 cm	Average annual snow depth

The effect of snow depth on suitability for development depended on more considerations than just elevation. Wind and exposure


TRUCKEE
HWY 80
HWY 267
HWY 89
KINGS BEACH
HWY 28
0
1
2
3
KILOMETERS
LEGEND

SOURCE: EDAW for Trimont Land Co.

FIGURE III - 5

NORTHSTAR SLOPE ANALYSIS

determined the extent of the snow hazard. Estimated snow depths were therefore correlated with an exposure map to produce the following classifications:

-	Below 150 cm	Any direction
-	150 - 230 cm	South facing slope
-	150 - 230 cm	East and west facing slopes
-	150 - 230 cm	North facing slopes
-	Over 230 cm	Any direction

6. Conflict Identification Summary

By comparing the initial proposed development plan with clear overlays of the various physical features, it was possible to identify where major or minor conflicts occurred between the proposed development and the land use capability of the Northstar property. The significance or magnitude of the identified conflicts was dependent upon the degree to which problems arising in these areas could be ameliorated. Typically, vegetation types and density, soils, exposure, and snow depth were less serious constraints than are slope and major drainage conflicts. Where several conflicts or development constraints coincided, then the feasibility of development was increasingly reduced. A composite map showing these combined conflicts compared with the development plan served as a guide for the best location for the eventual development of Northstar-At-Tahoe.

In making the composite map (see Figure III-6) primary, and secondary conflicts were considered as follows:

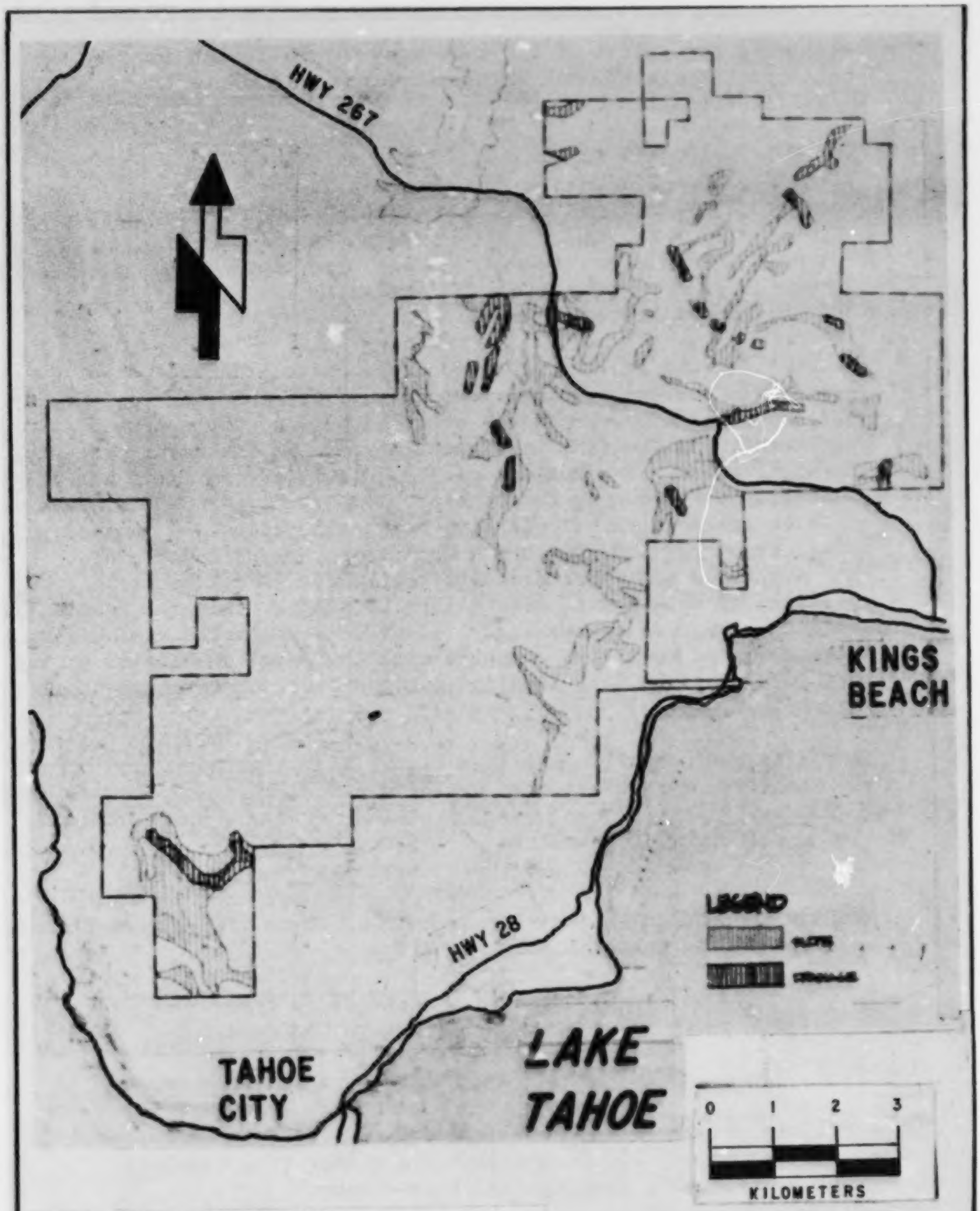
-	Primary Constraints	Slope Drainage

Areas with conflicts of either or both of these primary constraints were considered unsuitable for development.

-	Secondary Constraints	Vegetation types Vegetation density Soils Exposure and snow depth

Conflicts arising from these secondary constraints represented variances in cost and design controls rather than absolute constraints on the feasibility of development.

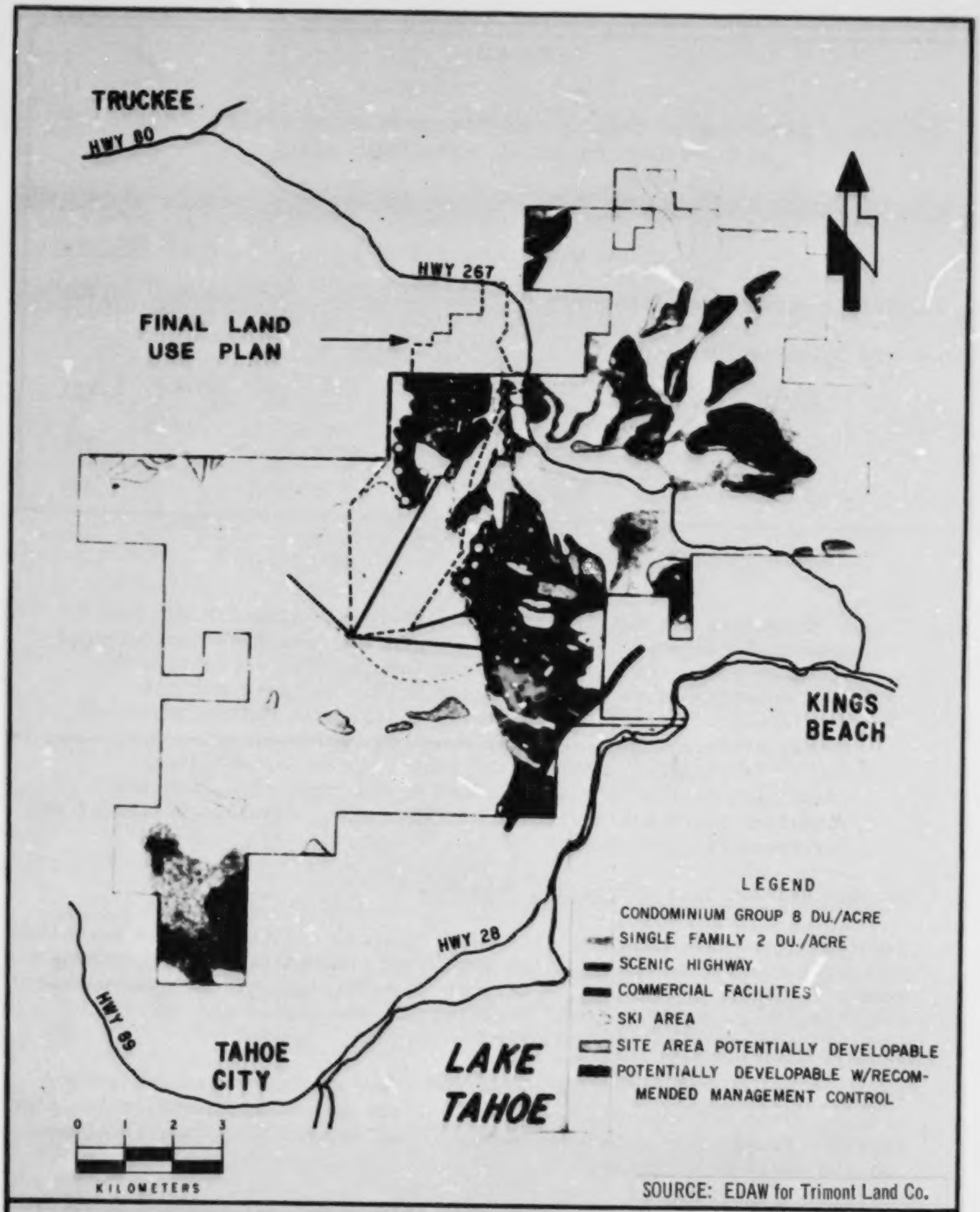
This composite was made and entitled "Revised Potential Development Areas" (see Figure III-7). When combined with the initial proposed development plan (see Figure III-3), it is apparent that the total areas involved in the "potential" and the "proposed"


HWY 267
KINGS BEACH
LEGEND
HWY 28
TAHOE CITY
LAKE TAHOE
0
1
2
3
KILOMETERS

SOURCE: EDAW for Trimont Land Co.

FIGURE III - 6

NORTHSTAR PRIMARY CONFLICTS


TRUCKEE
HWY 80
HWY 267
FINAL LAND USE PLAN
KINGS BEACH
HWY 28
HWY 89
TAHOE CITY
LAKE TAHOE
LEGEND
CONDOMINIUM GROUP 8 DU./ACRE
SINGLE FAMILY 2 DU./ACRE
SCENIC HIGHWAY
COMMERCIAL FACILITIES
SKI AREA
SITE AREA POTENTIALLY DEVELOPABLE
POTENTIALLY DEVELOPABLE W/RECOMMENDED MANAGEMENT CONTROL
0
1
2
3
KILOMETERS

SOURCE: EDAW for Trimont Land Co.

FIGURE III-7
REVISED POTENTIAL DEVELOPMENT AREAS - 1969

TABLE III-1

COMPARISON OF INITIAL PROPOSED DEVELOPMENT AREAS
WITH REVISED POTENTIAL DEVELOPMENT AREAS

	HECTARES
Initial Proposed Development	2,702
Revised Potential Development	
• Readily Developable	1,285
• Developable with Management Controls	604
TOTAL	1,889

developments are not drastically different. Although the revised potential development areas are 30 percent less than the original proposed plan, the main difference involves the relocation of development to more suitable areas. (The ski area was not considered a part of the development since its determinants are widely different from those of housing, roadways, commercial areas, etc.) Table III-1 compares the proposed developable areas identified in the initial proposed development plan with the potential developable areas identified after detailed review of the environmental constraints.

D. Recommended Conflict Mitigation Measures

Based upon the evaluation of the prime physical features of the Northstar property, several recommendations were made concerning site selection, manner of construction, and development feasibility. The recommendations were made to guide development construction and lessen the impacts of identified environmental conflicts.

Riparian Areas. The riparian areas are those along streams and around springs where the vegetation is particularly dense due to available water supply. These areas were recommended to be managed such that development impacts would be minimized.

1. Any diversion reducing water available to a riparian channel should be accompanied by thinning of the trees and vegetation to within the supportable limits of the reduced water supply.

2. Trees which may fall and block channels during floods, as well as any fallen trees and logs adjacent to channels, should be removed.

3. Trees which are close to the channel or in such a position as to cause floating debris to lodge against them should be marked for removal.

4. The cost of maintenance of riparian vegetation should be covered by returns from harvest of suitable trees.

Aspen Groves. The aspen groves represent a great asset to the Northstar development area. Their continued existence is dependent upon adequate water supply. Any diversion of water from them was recommended to be conducted with care since a thicket of dead trees could result. The need to thin aspen stands which had grown to exceed their water supply was identified.

Meadows and Willow Thickets. Meadows such as Sawmill Flat and the Willow and Beaver Pond area within the West Martis Creek drainage represented poorly drained soils, fairly high in fertility. The removal of grazing from them would create a succession toward Willow and Alder brush. In order to maintain herbaceous meadow vegetation, it was deemed necessary to have either planned grazing, late fall burning, or mowing of these meadows. The general principle was that the meadows, as they existed, were the result of past effects of human use as well as their natural environment. To the extent that a change in these conditions would be brought about by the development, the meadows would also change.

Erosion Hazards. The specific soil and geologic types determine the extent of possible erosion problems. Most erosion is the product of road cut and fill operations. Road cuts must be kept to a minimum. The revegetation of disturbed surfaces with native vegetation by encouraging natural invasion or by artificial plantings was recognized as an absolute necessity.

Fertilization. Most of the soils of the Northstar property are high enough in fertility for native vegetation. However, any nonnative or high density plantings that may be desirable for slope stabilization or local landscaping would require fertilization. It was recommended that this should be done only on those sites where fertilizer application will not change the quality of water flowing from the area.

Rocky Areas. Rocky areas are found throughout the Northstar property. These outcrops were expected to inhibit development where the rocks were loose, talus material lying at the angle of repose; undercutting and frost would cause slope creep of rock debris.

Drainage. Drainage channels were to be provided at the toe of impervious areas, such as road cuts or large impervious surfaces, such that gully formation would be avoided. This involved lined channels where the runoff exceeded the infiltration capacity of the collection area. Diversion of drainage to fill slopes or to the intersection of fill slopes and natural slope grade was to be avoided unless a lined channel was provided. Particular attention was needed at culvert and ditch outlets. Physical structures for energy dissipation were needed if there was insufficient natural capacity at the site to absorb the impact of the concentrated flow. Concentrations of runoff greater than the capacity of natural channels required lined channels. The inlets to culverts behind fills required devices to trap debris and sediment from entering the culvert.

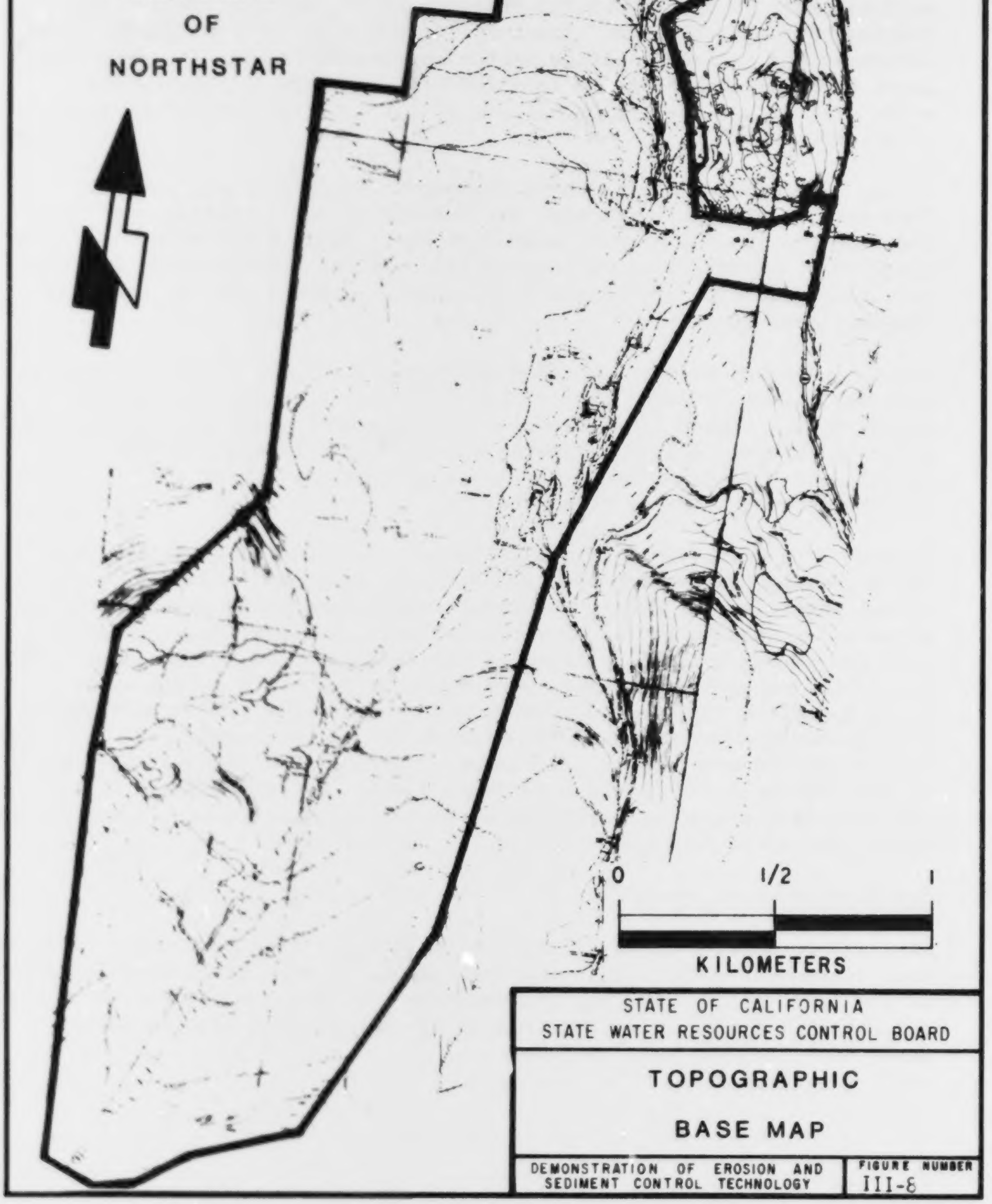
High Infiltration Capacity Soils. The soils of the Northstar property all have high infiltration capacities. They are typically brown forest soils developed on andesite and have good structural stability. As a result, the infiltration rates of undisturbed areas are very high. The subsurface drainage is good due to the very permeable geologic strata. The main recommendation for large surface runoff concentrations was that, insofar as possible, high drainage flows should be directed to natural channels. If high concentrations of surface runoff from roads and other similar impervious areas are placed out on slopes of residual soil, the water may wash deep new channels into the slopes. It was recognized, however, that small discrete drainage water discharges could be easily infiltrated in undisturbed areas adjacent to development sites.

Water Quality. The good structural stability of the soils found within the Northstar property was expected to result in water which clears rapidly after storms and generally to have low suspended sediment content. Therefore, any deterioration in water quality due to sediment was expected to be related to disturbance mainly in the form of road cuts and fills. It was recommended that fills be well compacted and have drainage regulated so as not to adversely affect the low sediment regime of the streams.

Slope Steepness. It was determined that areas of the Northstar property with slopes less than 15 percent may be readily developed. Slopes between 15 and 25 percent should be developed only under exceptional circumstances. All development should be prohibited from areas steeper than 25 percent.

Snow Depth. It was recommended that all developments should be excluded from areas with greater than 229 centimeters of snowfall.

Exposure. It was recommended that all development be prohibited from north facing slopes with greater than 152 centimeters of snowfall. All other areas would be able to sustain development from the standpoint of exposure and snow depth.


TOPOGRAPHIC
BASE MAP
OF
NORTHSTAR
0
1/2
1
KILOMETERS

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

TOPOGRAPHIC

BASE MAP

DEMONSTRATION OF EROSION AND
SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER
III-8

E. Revised Site Selection

In 1970, based upon the continued reassessment of the four cornerstones of the Northstar planning process (market study, profitability, government agency coordination, and site analysis), the Northstar developers made the decision to reduce the scope of the project to approximately 10 percent of the original 10,500 hectare tract. The reduced Northstar site was almost entirely within the West Martis Creek watershed and entirely outside of the Lake Tahoe basin. The West Martis Creek site was chosen due to location of ideal natural terrain for a ski area within the upper portions of the watershed below the summit of Mt. Pluto.

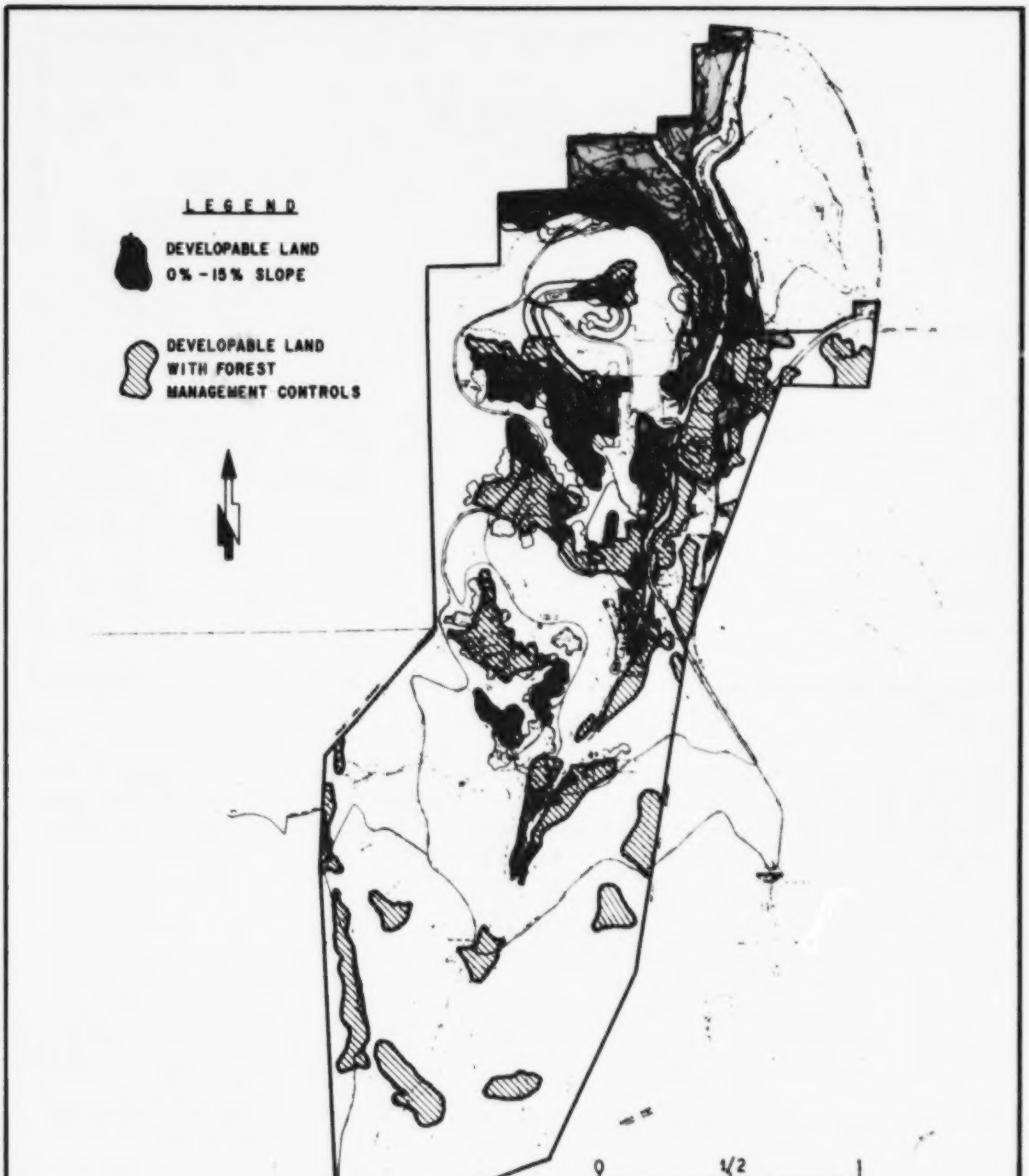
It was determined early in the marketing-economic analysis process, that the inclusion of extensive ski facilities was essential for the economic success of Northstar-At-Tahoe. Thus, the remainder of the detailed planning effort was concentrated on the 1,036 hectare portion of the original 10,500 hectare tract which contained the ski bowl and proposed base facilities.

For the purposes of more detailed planning, a 1:4,800 scale topographic base map with 15.2 meter contour intervals was prepared from aerial photographs. Figure III-8 depicts the topographic base maps which were prepared for the revised Northstar site. The Northstar planning consultants then prepared an even more critical review of the development potential of this area.

Further detailed review and evaluation of the prime physical features (slope, soils, vegetation type and density, drainage, exposure, and visual amenities was made. Potential development areas were defined as those areas which could be developed without any significant conflict with the prime physical features of the landscape. Potential development areas with management controls were areas where conflicts did exist, but where conflicts represented variances in the cost of development rather than absolute constraints on the feasibility of development. A summary of the developable land areas of Northstar within and adjacent to West Martis Creek is shown in Table III-2. For the most part, the ultimate development of Northstar-At-Tahoe conformed quite closely to the areas identified in Figure III-9.

F. Ski Slope Suitability Model

It was determined that the final design of the entire development must be closely linked to the design and location of the ski area. Further study of the area involved the use of computers for a more detailed analysis of the ski hill area and the West Martis Creek watershed than would be achieved by conventional methods.


LEGEND
DEVELOPABLE LAND 0% - 15% SLOPE
DEVELOPABLE LAND WITH FOREST MANAGEMENT CONTROLS
0
1/2
KILOMETERS

SOURCE: EDAW for Trimont Land Co.

FIGURE III-9. "DEVELOPMENT" AREAS AT NORTHSTAR IDENTIFIED DURING PRE-DEVELOPMENT PLANNING PROCESS

TABLE III-2

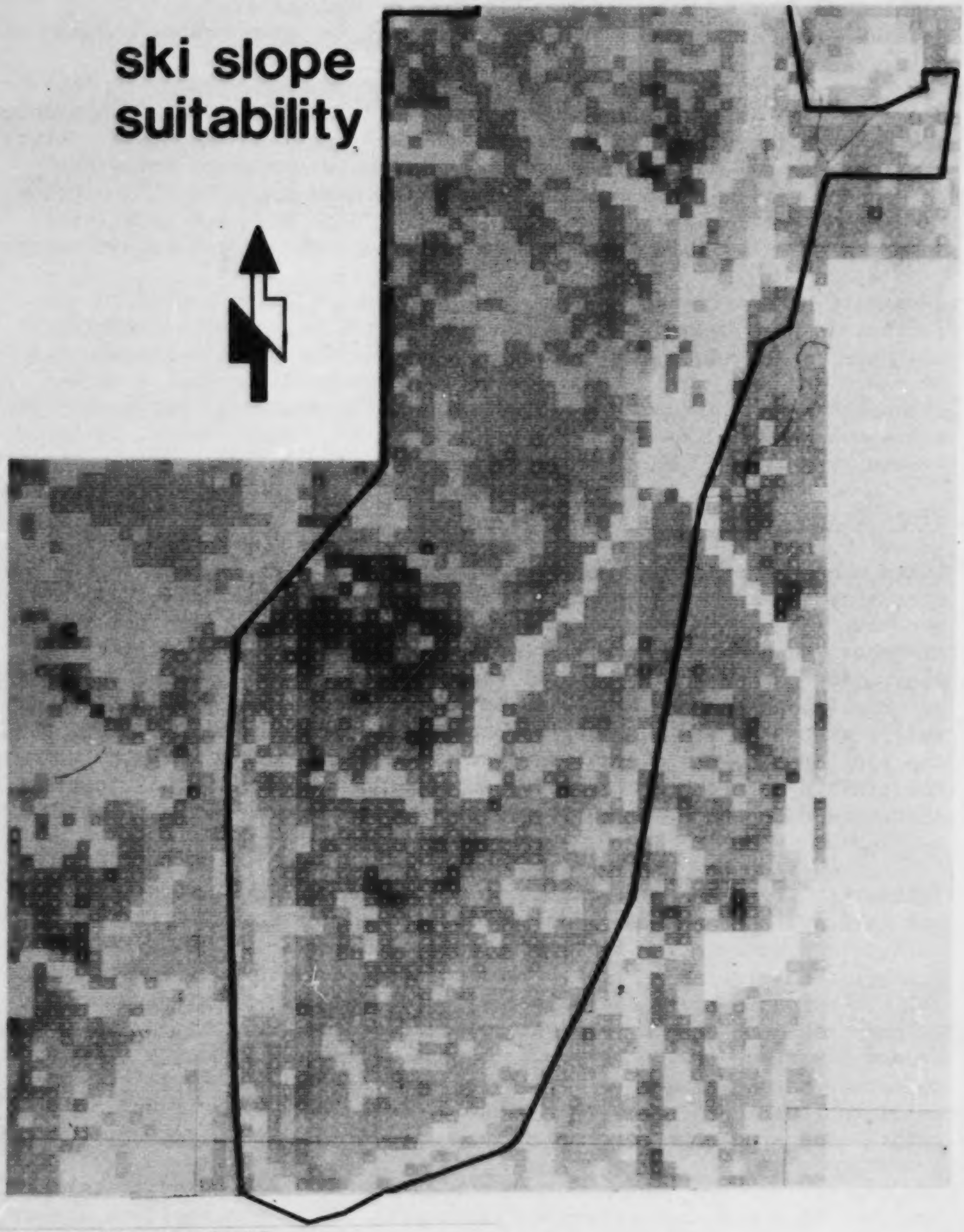
SUMMARY OF DEVELOPABLE AREAS ADJACENT TO WEST MARTIS CREEK

		HECTARES
Development Areas		
Potential		59.2
Potential w/Management Controls		96.0
	SUBTOTAL	155.2
Nondevelopable Areas		880.8
	TOTAL	1,036.0

The developers started with the establishment of generalized criteria for ski slope suitability based on comments provided by a variety of ski area specialists. The criteria developed are a hierarchy of values ranked as follows from most important to least important:

1. Slope
2. Surface water
3. Sun intensity
4. Snow depth
5. Vegetation type and age
6. Adjacent to streams
7. Vegetation density

On the basis of this value system, the developers were able to establish a matrix for combining the computerized mapping of the individual considerations. Slope and surface water criteria were of overriding importance in determining the location and extent of the ski area. A composite computer printout of the entire hierarchy of values is depicted in Figure III-10, which portrays a summary evaluation of ski slope suitability. The darker portions of Figure III-10 indicate the areas of the land most suitable for ski trail development. The lighter portions are the least suitable areas. Those portions of the terrain


ski slope suitability

SOURCE: EDAW for Trimont Land Co.

FIGURE III-10. SKI SLOPE SUITABILITY MODEL

adjacent to the surface waters of West Martis Creek were completely eliminated from consideration. Ultimately, the ski trails crossed West Martis Creek in a few locations for purposes of access only.

The ski slope suitability computer output was used to design the complete system of ski trails which were then checked again in the field. With the ski hill refinement provided by the computer program, Northstar's developers were able to establish the extent and location of a variety of development components: ski lifts, ski lodge and base facilities, opportunities for ski-in/ski-out condominiums, and access requirements.

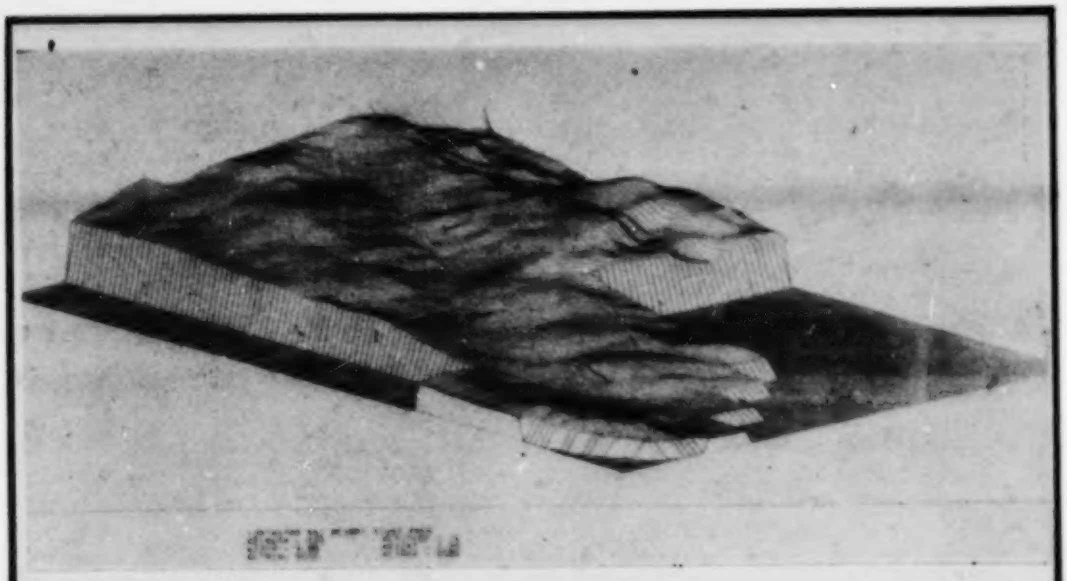
A variety of additional computer analyses were also conducted to facilitate plan layout. These are exemplified by the site isometrics analyses portrayed in Figure III-11. The site isometrics allowed the planners and designers of the Northstar development to gain a three-dimensional appreciation of the terrain of the Northstar property. The views depicted in Figure III-11 are looking to the southwest, up the West Martis Creek Valley, from two different elevations.

G. Final Development Plan

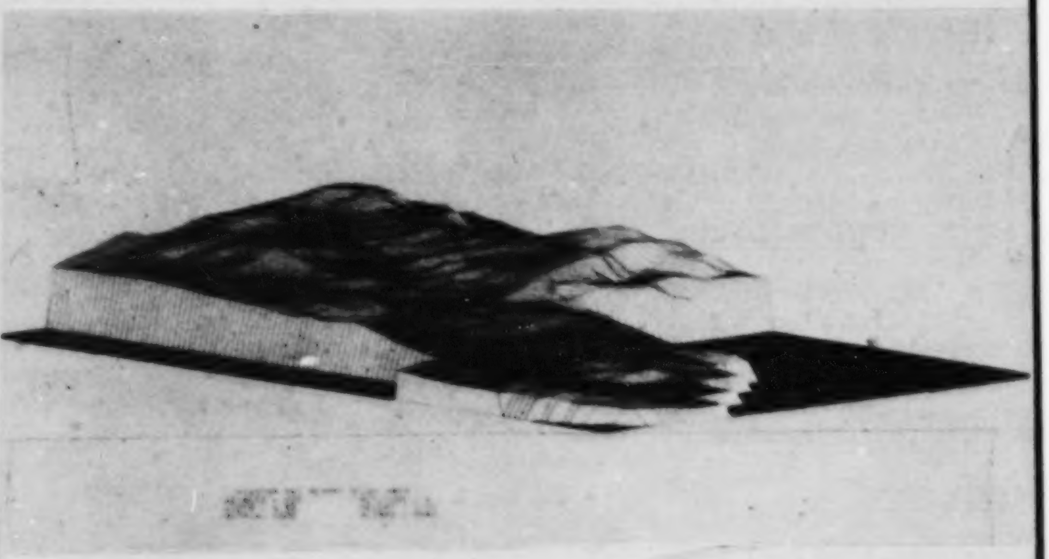
Based upon the evaluation of the prime physical features of the Northstarstar property and considerations pertaining to marketability, profits, and government agency review, the final development design for Northstar-At-Tahoe was prepared by the planning team. As was true for the evaluation of the prime physical features leading to final site selection, primary (slope and drainage) and secondary (vegetation type and density, soils, exposure, and snow depth) constraints were the main factors guiding the final development layout design. Areas conflicting with the primary constraints were considered unsuitable for development. Only in rare instances and with additional expense were areas with primary constraints developed.

Initially, the complete development of the Martis Creek watershed area was anticipated to extend over a period of approximately eight years and include approximately 3,115 condominium-type units and 585 single-family 0.1 hectare lots. The planned land use includes, in addition to the residential use, a village commercial area, highway service commercial at the project entrance, ski resort, golf course, recreation center with tennis courts and swimming pool, corporation yard for county maintenance equipment, fire and police facilities, water treatment facilities, wastewater reclamation facilities (for golf course irrigation), ski maintenance area, forest reserve, and open space area.

The Big Springs Inn, which serves the skiers at the base of the slopes, has over 16,000 square meters of floor area. This inn contains space for multipurpose food and beverage areas, small ski shops/accessories, pubs, ski school and lockers, offices and emergency living quarters,



ALTITUDE . 15



ALTITUDE . 8

SOURCE: EDAW for Trimont Land Co.

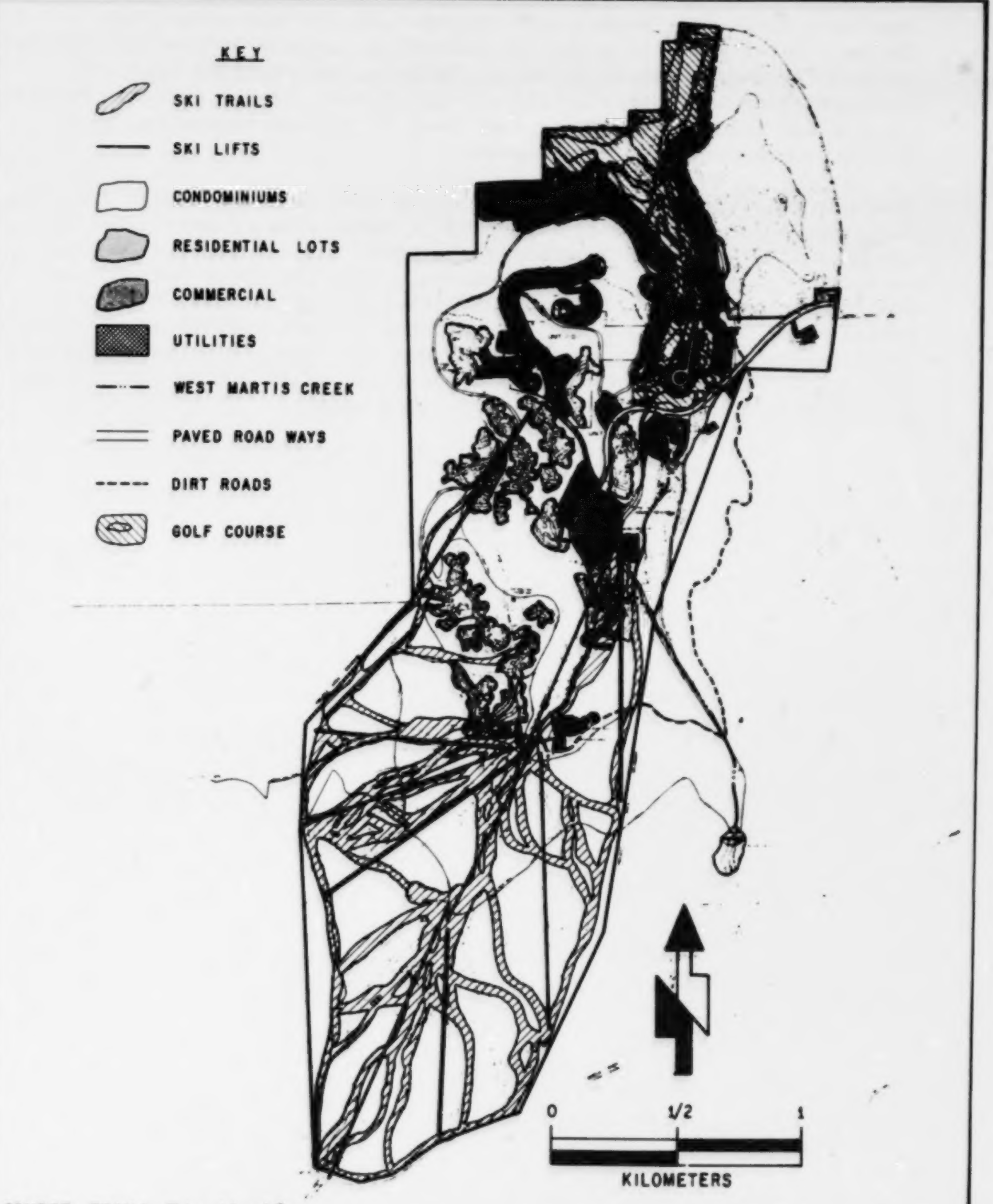
FIGURE III - 11

NORTHSTAR SITE ISOMETRICS

TABLE III-3

NORTHSTAR LAND USE PLAN SUMMARY

	PLANNED	
	HECTARES	PERCENT
RESIDENTIAL		
Single Family Homes	14.7	
Condominium Units	21.0	
SUBTOTAL	35.7	3.4
COMMERCIAL		
Village Center	1.2	
Ski Area	4.0	
Highway Service	0.8	
SUBTOTAL	7.0	0.7
UTILITIES		
County Services	3.2	
Other	4.9	
SUBTOTAL	8.1	0.8
ROADS AND PARKING		
Condominiums	18.2	
Village Center	4.5	
Public Roads	25.1	
SUBTOTAL	47.8	4.6
RECREATIONAL FACILITIES		
Ski Trails	131.6	
Golf Course	64.8	
Other	2.4	
SUBTOTAL	198.8	19.2
TOTAL DEVELOPED AREA	297.4	28.7
OPEN SPACE		
Ski Area Open Space	413.1	
General Open Space	281.3	
Private Open Space	44.0	
	738.4	71.3
TOTAL PROJECT	1,035.8	100.0


KEY
SKI TRAILS
SKI LIFTS
CONDOMINIUMS
RESIDENTIAL LOTS
COMMERCIAL
UTILITIES
WEST MARTIS CREEK
PAVED ROAD WAYS
DIRT ROADS
GOLF COURSE
0
1/2
1
KILOMETERS

SOURCE: EDAW for Trimont Land Co.

FIGURE III-12. FINAL LAND USE PLAN FOR NORTHSTAR - 1970.

auxiliary first aid, decks, and lounges. The village commerical facility development is utimately planned to include medium and highrise residential units, specialty shops, markets, multipurpose food and beverage areas, and other retail service areas. At the present, however, the village commerical area is less than 30 percent completed, with 10,700 square meters of floor space.

Fourteen ski lifts, principally radiating from the Big Springs Inn area, are planned for the ski area which has a total area of approximately 486 hectares. These facilities are designed for an ultimate peak-day capacity of approximately 10,600 skiers. Only six lifts and one tow have been constructed. The ski facilities are essentially for the preferential use of the Northstar-At-Tahoe Project residents; therefore, the ultimate development concept provides for only a limited number of day skiers. Table III-3 summarizes the final planned land use for the Northstar-At-Tahoe, Martis Creek watershed area.

SECTION IV

DEVELOPMENT CONSTRUCTION CRITERIA FOR NORTHSTAR

The planning process which produced the Northstar development did not end once the final layout of the development had been chosen. Considerable additional planning had to be conducted to address potential problems that could appear during the construction phases of the project. Of particular interest from the standpoint of effective erosion control were the various studies and controls which were developed prior to the start of construction. These included:

- Logging Controls
- Site Specific Soils Analysis
- Environmental Impact Reporting
- Vegetative Maintenance Recommendations

A wide variety of other preconstruction planning activities were conducted to address problems pertaining to architectural design, sewage treatment, water supply, parking configurations, specific recreational amenities, zoning problems, development phasing, and traffic circulation. These subject areas were not critical for the control of erosion problems and, thus, will not be discussed.

A. Logging Controls and Ski Trail Clearing

The ski area at Northstar was designed to have minimum environmental impact. Only narrow trail areas were cleared for ski runs which were typically less than 50 meters wide. Less than 30 percent of the upper watershed was cleared for ski trails. In most instances, storm runoff and eroded materials from the initially disturbed ski trails were discharged to adjacent undisturbed areas. This was accomplished by two methods:

1. Sloping the cleared ski trail diagonally across the "fall line" or in a downslope direction. This allowed storm runoff and other drainage waters to be "filtered" through adjacent undisturbed areas.

2. Water bars and gently graded contours were used extensively to direct cleared slope drainage to adjacent undisturbed areas.

Logging and tree removal were required for the siting of development structures and for the construction of ski runs. Criteria were established by the county to minimize adverse impacts on the terrain and on water quality. Logging activities can cause extensive soil disruption and lead to increased runoff concentrations from disturbed areas (6,7,8,9). Erosion rates from areas adversely affected by logging activities may increase dramatically. The following criteria were developed at Northstar, as required by Placer County, to minimize these impacts:

1. General

   - The natural ground surface was disturbed as little as possible and rubber tired equipment was used whenever practicable.
   - No stumping was permitted except where specified for structural siting, hazard reduction, or other related purposes.
   - Existing slash was disposed of offsite by hauling to a disposal area or onsite by gathering and piling for burning.
   - Existing grasses, weeds, ferns, and ground cover, such as squaw carpet and manzanita, were left in essentially an undisturbed state.
   - No trail work was conducted without onsite expert supervision.

2. Trails and Lift Lines

   - Falling timber into residual stands was avoided.
   - Fallen logs, trees, stumps, and slash were removed from trails.
   - Rocks over 60 centimeters in diameter were placed to the side of trails.
   - Any projecting boulders (over 2 meters) were drilled and shot with low percentage dynamite.
   - Berms on roads crossing trails were flattened on cut side and rounded off on lower side.
   - Small seedlings, buck brush, manzanita, etc., adjacent to trails were left in place in order to feather edge.
   - Decayed, old, or rotten downed timber was flattened by a tractor or other equipment.
   - Gouging soil with bulldozer blades was prohibited. Excavation was only allowed to adequately divert potential storm and snowmelt runoff.
   - Logs snaked to a landing were thoroughly delimbed and sectioned to minimize damage to residual undergrowth, ground cover, and timber.

- Stumps were removed either by splitting or by grinding. This resulted in minimum ground disturbance.

3. Areas Between Trails

   - Dead, damaged, diseased, or leaning trees were removed.

   - Slash and debris on ground were flattened as much as possible.

   - Willows, alder, aspen and seedlings in these areas were left intact.

B. Site Specific Soils Analyses

Prior to the construction of each subunit of the development, detailed soils reports were prepared to notify the design engineers of any special problems which might be encountered. In addition, the soils reports provided the appropriate construction criteria which were required in each instance. The following specific construction criteria was provided by the individual soil analyses (10):

1. Trenching

   - Clearing and grubbing was kept to a minimum in such a manner that the existing natural appearance would be preserved or reestablished at the end of construction.

   - Top soil was usually thicker than 0.3 meter; therefore, top soil was excavated to a maximum depth of 0.5 meter and stockpiled separately for later use as the top portion of the backfilled trench.

   - Check dams were required for erosion control of the backfill. They were installed across the trench where the ground surface slope along the alignment was greater than 10 percent. Check dams were also installed on the up-hill side of major creek crossings to prevent direct discharge to surface waters. The check dams were constructed by placing internesting "sackcrete" from 0.3 meter above the top of the pipe to 0.15 meter above the ground surface.

2. Roadway, Parking Lot, and Condominium Construction

   That portion of the Northstar development which is most heavily developed for residential and commercial facilities is located in an area having silty top soil containing decaying vegetation and roots, cobbles, and boulders in some areas. The topsoil is underlain by sandy silt with a varying amount of cobbles and boulders in brown-yellow tuffs and breccias of volcanic origin. The original roadway alignments were covered by a thin growth of grasses in places with localized thick pine needle covering below the trees and, in some areas, heavy brush and trees. Surface runoff was very light, even in the spring and fall seasons.

Only a few major construction difficulties were anticipated. These included excavation in dense layers of cobbles and rocks with occasional large boulders or bedrock and localized high groundwater problems. The thickness of top soil to be removed and stockpiled for later revegetation was determined in the field by the soil engineer. It was kept at a minimum, however, consistent with obtaining a reasonably good subgrade. For estimating purposes, an average of about 0.5 meter depth of top soil removal was recommended.

Proposed cut slopes could be excavated at Northstar up to 2:1 without creating exceptional erosion problems. When hard rock was encountered, the cut slopes were steepened to 1:1 and even steeper.

Compacted fill slopes were not constructed steeper than 2:1 and care was exercised in draining the surface of the adjacent areas away from the slope face. Where natural slopes were steeper than 5:1, the surface was benched continuously to provide level steps on which to base the fill. All fill slopes were compacted and leveled to provide a surface free of loose material which would be subject to erosion or sloughing.

C. Environmental Impact Reporting

To provide information to the county on the environmental impacts of the various proposed subunits of the Northstar development, a series of environmental impact reports were prepared by the development planners(11). Not only did these reports assist the county in their obligations of meeting the requirements of the California Environmental Quality Act (CEQA) of 1970, but they also made recommendations to the developers on how expected problems should be addressed. The recommendations made in the environmental impact reports pertaining to erosion control for trenching operations, roadways, and parking lot construction were similar to those made in the various soil reports mentioned previously. The main thrust of the recommendations pertained to problems expected to be encountered in the construction of condominium and residential subunits.

1. Home Sites and Condominium Areas

The following criteria were used in determining which sites should be developed for private home sites and condominium areas.

- Natural slopes should not exceed 15 percent.
- The soils must be structurally stable, not excessively stony, and free of rock outcrops.
- Vegetation density of developable areas should not exceed 60 percent.

- Development should not violate existing flood plain or wet meadow areas. Existing water courses should not be altered.

The following is a brief summary of the environmental impacts pertaining to erosion control and sediment transport which were identified for a typical condominium construction site:

> "Some ground compaction does result from the siting of condominium units. Rubber tired equipment, used where possible, serves to minimize soil disturbance and, thus, reduce erosion potential in the siting process. The only major potential for erosion occurs on roadcuts and fill areas. The surface drainage is slightly increased especially in paved areas due to a concentration of runoff. Attention must be given to evenly distribute the runoff to existing natural drainage channels. trenches dug for utility and service may impede, to a limited extent, subsurface drainage and create a visual scar dividing the surface landscape for a short time. Few, if any, areas pose revegetation problems if adequate precautions are taken during construction (11)."

Recommendations for minimizing erosion control and sediment transport problems for a typical condominium unit included:

- In those areas where ground cover has been removed due to cuts and fills or other construction processes, revegetation should take place to reduce erosion and, secondly, to lower dust conditions.

- All cuts higher than 1.5 meters (vertical) should receive the following special treatment.

    - Cuts should be sloped to 2:1 and the upper portion of the slope rounded off. A 2:1 slope is necessary for adequate replacement of topsoil.

    - Topsoil should be replaced to a depth of 15 centimeters on these cuts and then compacted with a sheepsfoot roller.

    - The topsoil should be replaced in the spring of the year, allowing for a slight erosion of the exposed subsoil, thereby resulting in a surface that will greatly facilitate the bonding of topsoil to subsoil. At this time, hydromulching with a native seed content and plantings for erosion control should be conducted.

    - Cuts that expose rock surfaces should be left as such and treated as rock outcroppings, Such cuts should be made at the maximum safe slope and not at the two 2:1 slope required for the replacement of topsoil.

All fill slopes should be treated in the same manner as outlined for the cut slopes. Topsoil should be stockpiled at several points along the access road right-of-way that are convenient to the major cuts and fills that are involved. This topsoil should be stripped from the road right-of-way and cut and fill slope areas that are not excessively stony.

- Increased surface runoff must be recognized as an exponential result of paving and surfacing.
- The increase in water runoff should be directed to natural drainage channels to avert overland travel and resulting surface erosion, stream sedimentation, and new surface channels.
- All equipment should avoid rocky outcroppings due to fragility of the vegetation characteristic to them and due to the possibility of slope creep.
- All service utilities should be placed in common trenches to minimize the number of trenches excavated per unit.
- Trees to be preserved should be wrapped, staked, or protected by other means to avoid bark damage during the course of construction. A rope barrier around groups of trees or other vegetation would be adequate. No salt should be used on road surfaces for winter safety, except where the addition of sand provides inadequate safety control.
- Where sand is used on roads for winter safety, adequate catch basins should be installed and serviced regularly in order to provide for the settlement of particular matter from the pavement runoff prior to any entrance to Martis Creek or any of its drainages.
- Care should be taken to avoid aspen and other larger trees during construction.
- West Martis Creek and any wet areas should not be crossed with any vehicle or equipment during construction.

2. Foundation Systems

A further in-depth analysis was prepared to determine the comparative environmental impacts of post and beam construction as opposed to perimeter foundations for condominiums. Comparisons were made from the standpoint of soil disturbance, area disturbance, and visual conflicts in areas of 0 to 15 percent slope and areas of 15 to 25 percent slope.

- The Disturbance of Soil for Foundations

  Calculations demonstrated that the average volume of soil removed per unit with the post and beam construction would be 31 cubic meters. The average volume of soil per unit utilizing a perimeter foundation would be approximately 20 cubic meters, which is 35 percent less than the post and beam construction.

- Disturbance of Soil for Construction

  Post and beam construction requires a continuous pathway 4 meters wide around the perimeter of each building group or approximately 70 square meters per unit. This pathway serves both foot traffic and traffic from the 60-ton crane which is required for the replacement of the precast concrete footings. The movement of the crane compacts the soil, necessitating the removal of all vegetation in the area of the pathway, and place in jeopardy all trees that are close to the edge of the path. Perimeter foundations also require a 4-meter wide pathway around each building group. However, this pathway serves only foot traffic and occasional traffic light construction equipment which deliver concrete blocks and reinforcing steel. These materials are stockpiled within a 4-meter path for each unit.

- Drainage and Revegetation

  The soils of the Northstar property generally possess high ecological suitabilities for buildings and do not pose many problems with regard to a change in foundation type. The recovery period for vegetation in these soils is generally rapid depending on the extent of the original disturbance. The main impact involved with post and beam construction on slopes greater than 15 percent is the relative bearing capacity of the soil. Due to the lack of substantial clay layers within Northstar, the post and beam foundation type is a method in which bearing capacity and soil drainage create few problems.

  The perimeter foundation, on land with less than 15 percent slope, creates less disturbed surface area and ground compaction during construction than post and beam foundation types. The foundation wall serves as a barrier to subsurface and surface drainage for the entire 36 meter width of an average condominium group. Due to the presence of a moderately high water table in some units, changes in subsurface drainage were expected to occur. In any seasonally wet area, it was recommended that subsurface drainage pipe, block spacers or other similar means be installed to enable drainage to be continuous. In areas where downslope vegetation relies on subsurface water drainage, this installation is particularly important to insure the stability of the vegetation. Surface drainage should be directed to natural drainage channels. The soils of the lower areas which support sage brush and Jeffrey pine contain higher percentages of clay. The subsoil permeability and the soil drainage is generally slower in these soils and this should be accounted for by the installation of subsurface drains.

The post and beam construction on land with under 15 percent slope was not expected to hamper the subsurface drainage to any extent due to the fractured nature of soil. The majority of subsurface drainage through the porous substrata would be conducted around the embedded post. The construction process of digging the holes and placing the post and beams disturbs and compacts the soil to some extent but, due to the high rock content of the soil, compaction would not necessarily create revegetation or runoff problems. The post and beam construction on land with slopes greater than 15 percent results in similar impact as those on slopes less than 15 percent. The relative erosion potential increases from slight to moderate in these soil types on areas greater than 15 percent slope regardless of foundation type. Due to the particle size and distribution of these soils, the erosion hazard does not present extensive problems. If construction practices are carefully monitored, there should be no subsequent soil drainage or revegetation problems on the site with either foundation type.

- Visual Amenity

  Post and beam construction provides an interesting and esthetically satisfying design relationship between the building and the land. This relationship is most appropriate in certain situations, such as steep slopes (15 percent) where perimeter foundations would present a massive and unpleasant face on the downhill side of the unit; on rocky lands where it would be extremely difficult to excavate for linear foundations or on wetlands where no building contact with the surface is desired. In almost every other situation, perimeter foundations that are pleasantly detailed and planted are as esthetically acceptable as post and beam construction. When post and beam construction is to be used, it does provide the potential for the accumulation of debris, vegetative, or other beneath the unit. This condition must be overcome by active maintenance.

The environmental impact of post and beam construction is slightly greater on slopes of 0 to 15 percent impact than that caused by perimeter foundations. Specifically in the areas of soil compaction and vegetative disturbance, these particular impacts do not increase significantly on the steeper slope conditions and can be ameliorated by thorough construction, supervision, and revegetation of disturbed areas. Perimeter foundations on the steepest slopes have the esthetic disadvantage of massive downhill faces. Also, with parameter foundations, the amount of surface grading required for the satisfactory drainage of surface water around the building creates significant constraints in tight areas, such as the space between buildings or between buildings and parking lots.

3. Village Center Commercial Area

The environmental impact report prepared prior to the construction of the village center commercial area recognized the possibility of a substantial impact. It was recognized that much of the area would be paved or covered by other impervious surfaces.

The major drainage outlet from the Village Center discharges directly to Martis Creek east of the village after passing through an energy dissipator. The channel was rock riprapped at the outfall into Martis Creek to avoid extreme bank erosion. The total runoff intensity for peak storm, calculated for a mean annual precipitation of 90 centimeters, was 3,110 cubic liters per second with the velocity of 2.2 meters per second at the point of entering Martis Creek. The major impacts are sand and sediment load from road and walk surfaces and, secondly, possible vegetation and limnological damage if calcium chloride is added to the sand applied to road surfaces for winter safety. Based on Placer County Maintenance Department estimates, the total volume for sand normally applied per year to an area comparable to the village center and parking area is between 14 and 18 metric tons.

Recommendations given for mitigating adverse impacts due to the construction of the Village Center commercial area included:

- In order to insure compliance with the Porter-Cologne Water Quality Control Act (State of California) and Northstar's internal quality control standards, it is recommended that an adequate catch mechanism and energy dissipator, such as "bubbleup" catchment basin and sediment pond or other similar devices be installed and serviced regularly in order to provide for settlement of suspended sediment prior to outfall into West Martis Creek. There should be no significant deviation beyond natural background levels of turbidity and total suspended dissolved sediment load.
- The angle and slope of the outfall and the entrance of the outfall at Martis Creek should be such that minimum streambank erosion occurs at that point.
- All trees not marked for removal during the village construction should be chosen for their vigor as well as placement purposes. These trees should be wrapped or protected by other means to avoid damage during construction. Care should be taken to avoid severe ground compaction or disturbance of tree

roots. A radius comparable to one-sixth of the tree height should be roped off or protected by other means to avoid this excessive compaction and to allow for moisture and aeration in the root zone.

- Pathways and walkbridges should be constructed to control vegetation trampling and damage to creek and natural areas.
- Care should be taken to avoid overland flow where such flow may result in accelerated erosion.
- No salt should be used on road surfaces for winter except where the addition of sand proves to be inadequate for safety control.

D. Planting and Revegetation Management Program

Vegetation was recognized by the developers and planners as an integral component of the Northstar environment (12). It was also recognized that a development of Northstar's scope could not be constructed without some initial damage to the native vegetation. The purpose of the Planting and Revegetation Program at Northstar was to insure permanent and rapid recovery of disturbed areas.

Vegetative Analysis

The vegetative structure or "mosaic" was carefully examined and mapped at Northstar. The various subunits identified ranged from open, wet meadows and dry, shrubby areas at low elevation to the Red Fir climax communities on the upper slopes. The criteria which was chosen to characterize the several subunits included:

- The dominant species present.
- Age classes of the dominant species.
- The presence of species with a capacity to reproduce even when shaded by existing vegetation.

A total of 13 distinct subunits were identified within the West Martis Creek portion of the Northstar Creek property:

1. The Open, Wet Meadow subunit is recognized by an abundance of wet meadow grasses, Clover, Willow, and Alder, with scattered Jeffrey Pines. The history of the subunit is mainly grazing and some creek flooding. The meadow remains wet throughout the summer, due to poor drainage, and supports numerous wildflowers.

2. The Riparian subunit is characterized by a narrow zone of wet grasses and associated hardwood species of Aspen, Black Cottonwood, Willows, and Alders which create a winding strand of riparian protection and habitat for associated fauna.

3. The Wet Meadow-Forest subunit is in a visible state of change from wet meadow grass, Aspen, Willow, and Alder, to a mixture with Lodgepole Pine and White Fir invading from the exterior boundaries. These areas are extremely sensitive due to the dependence on water and the number of attractive wildflowers and hardwood species.

4. The Sage-Bitterbrush-Mule Ears subunit is the driest unit on the property and is characterized by the low-lying shrubs and numerous grasses and wildflowers. It occurs on the dark, heavy, high clay containing soils developed from andesitic rock.

5. The Jeffrey Pine-Sage-Mule Ears subunit is an open, dry area upslope from the creek and below the more heavily timbered areas. The scattered pines make up less than 40 percent of the cover but contribute significantly to the character of the subunit. This subunit occurs mainly on soil type boundaries from less acid to more acidic brown forest soils.

6. The Pine-Fir subunit represents an area which was, at one time, strictly pine-sage but has now been invaded by White Fir, manzanita, and associated species.

7. The Ceanothus-Manzanita Brushfield subunit is historically related to fire and depends upon fire for existence. The seeds of these species require heat of 200-300° Fahrenheit to germinate but, once established, sprout vigorously and tend to control the site. A gradual invasion of the Tobacco Brush and Greenleaf Manzanita by conifers over a 30- to 60-year period returns the site to its coniferous cover. The units on the property represent two stages of coniferous invasion.

8. The latter stage of the Ceanothus-Manzanita Brushfield subunit is is characterized by a similar mix of Tobacco Brush and Green Leaf Manzanita with a larger percentage of White and Red Fir. Some Jeffrey Pine is present as a remnant of the original fire and some younger trees have seeded along with the White and Red Fir but have not competed as favorably.

9. The White Fir-Red Fir-Jeffrey Pine subunit in the early stage is characterized by dense thickets of young White and Red Fir and Tobacco Brush with some Jeffrey Pine present. This subunit is generally the result of fire or clearcut logging and is one step towards the climax on the successional ladder. This vegetational subunit usually occurs on deep, brown forest soils such as Cohassett.

10. The White Fir-Red Fir-Jeffrey Pine subunit in the latter stage has progressed further in succession by shading out more of the bush species as well as establishing a lower story of White Fir and Red Fir seedlings. Some of the lower species present in the pure Red Fir forest start to appear in this subunit under the mature White and Red Fir.

11. The Fir-Pine subunit is characterized by an upper story of mature White and Red Fir with some Jeffrey and Sugar Pines and an understory of White and Red Fir.

12. The Red Fir - White Pine - Jeffrey Pine subunit occurs above the 2000 meter elevation and covers the majority of the upper ski area. Pinemat Manzanita replaces Squaw Carpet as the principal ground cover in association with Tobacco Brush and Chinquapin.

13. The Red Fir forest is the climax community and is characterized by heavy densities of Red Fir and small amounts of Chinquapin, Gooseberry, and Thimbleberry, in openings where light reaches the forest floor. Red Fir is the only major species tolerant enough to reproduce under its own heavy canopy.

The locations of each of these subunits within the Northstar Property is shown in Figure IV-1. The various plant species which were identified within each of the subunits are listed in Table IV-1. Once development occurred within the various subunits, it was recommended that disturbed areas should be replanted with species native to that subunit.

Revegetation Recommendations

The following recommendations were prepared by the Northstar planners to serve as a revegetation guide for areas disturbed during construction:

1. Condominiums

   - Concept

     - The condominiums have generally been designed to impart minimal impact on the site with units clustered to preserve open space. Native vegetation is preserved as much as possible.

   - General Recommendations

     - Remove brush to minimum of 50 feet from units for purposes of fire safety.

   - Upper Condominium Hill and Middle Condominium Hill

     - Ground covers should be Pinemat Manzanita, Newberry Penstemon, and Squaw Carpet.
     - Planting should occur after seeding disturbed areas with grass-legume fertilizer mix with Mule Ears added.
     - Jeffrey Pine, Sugar Pine, and Red Fir are recommended trees.
     - Recommended shrubs are Snow Berry and Thimbleberry, neither of which creates a major fire problem.

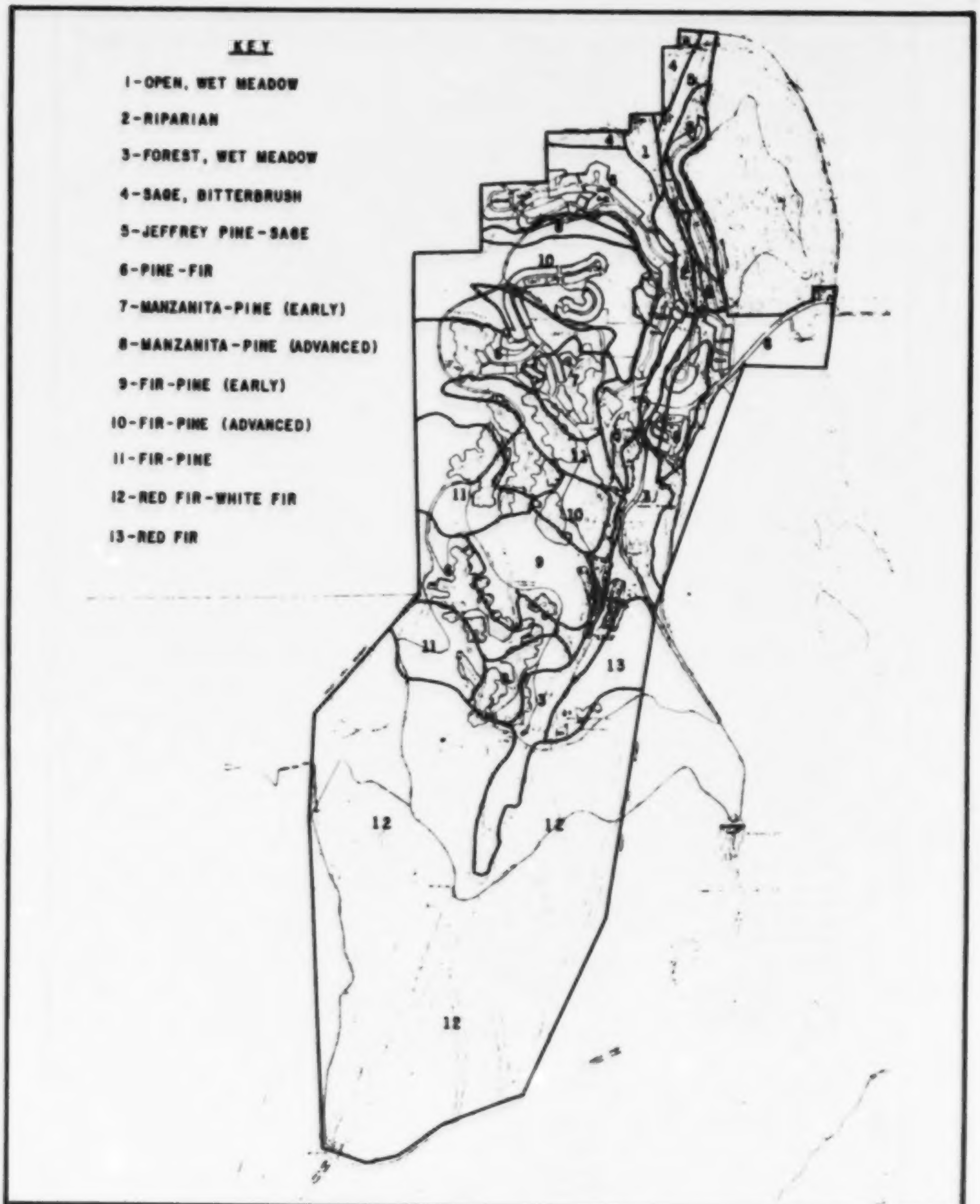

KEY
1-OPEN, WET MEADOW
2-RIPARIAN
3-FOREST, WET MEADOW
4-SAGE, BITTERBRUSH
5-JEFFREY PINE-SAGE
6-PINE-FIR
7-MANZANITA-PINE (EARLY)
8-MANZANITA-PINE (ADVANCED)
9-FIR-PINE (EARLY)
10-FIR-PINE (ADVANCED)
11-FIR-PINE
12-RED FIR-WHITE FIR
13-RED FIR

FIGURE IV-1. VEGETATIVE MOSAIC OF NORTHSTAR DEVELOPMENT.

TABLE IV-1: SPECIES COMPOSITION OR THE VEGETATIVE SUB-UNITS AT NORTHSTAR

No.	COMMON NAME	SCIENTIFIC NAME	SUB-UNITS 1	2	3	4	5	6	7	8	9	10	11	12	13
1	White Fir	Abies concolor					X	X	X		X	X	X	X	X
2	Red Fir	Abies magnifica								X	X	X	X	X	X
3	Yarrow	Achillea mittefolium	X	X	X										
4	Columbian Monkshood	Acomitium columbianum		X	X										
5	Wild Onion	Allium sp.		X				X	X						
6	Mountain Alder	Almus tenuifolia	X	X	X										
7	Serviceberry	Amelanchier almitolia			X		X	X			X	X		X	
8	Red Columbine	Aquilegia truncata	X		X										
9	Pinemat Manzanita	Arctostaphylos nev.								X	X	X	X	X	X
10	Green Leaf Manzanita	Arctostaphylos patula					X	X	X	X	X	X	X	X	
11	Sagebrush	Artemisia tridentata		X			X	X	X						
12	Lady Fern	Athyrium filix-femina									X	X			
13	White Brodiaea	Brodiaea sp.				X		X							
14	White Mariposa Lily	Calchortus venustus					X								
15	Pussy Paws	Calyptridium umb.					X	X	X						
16	Chinquapin	Castanopsis semp.			X			X			X	X	X	X	X
17	Indian Paintbrush	Castilleia pimetorum	X					X			X	X			
18	Squaw Carpet	Ceanothus prostratus					X	X	X	X	X	X	X		
19	Tobacco Brush	Ceanothus velutimus					X	X	X	X	X	X	X	X	X
20	Rabbit Brush	Chrysothamnus naus.				X	X	X	X						
21	Sierra Thistle	Cirsium californicum			X				X						
22	Meadow Daisy	(compositia)	X	X	X										
23	Sierra Morning Glory	Convolvulus villosus				X									
24	Sierra Shooting Star	Dedecatheon jeffreyi	X		X										
25	Larkspur	Delphinium scopulorum			X										
26	Horsetail	Equisetum arrense		X	X										
27	Queen Anne's Lace	Eulophus bolander	X			X	X	X							
28	Gayophytum	Gayophytum dittusum				X	X	X	X						
29	Gilia	Gilia sp.				X									
30	Cudweed	Gnaphalium sp.				X									
31	Bigelow Sneezeweed	Helenium bigelovii	X		X										
32	Cow Parsnip	Heracleum lanatum			X										
33	Tiger Lily	Lilium parvum		X	X										
34	Washington Lily	Lilium washingtonianum							X	X					
35	Brewer's Lupine	Lupinus brewerii	X		X	X	X				X	X	X		
36	Mint	Mentha arvensis	X	X	X										
37	Yellow Mimulus	Mimulus guttatus	X	X	X										
38	Monardella	Manardella nana				X									
39	Penstemon	Penstemon sp.					X	X	X						
40	Jeffrey Pine	Pinus jeffreyi	X	X	X	X	X	X	X	X	X	X	X	X	X
41	Sugar Pine	Pinus labertiana						X			X	X	X	X	X
42	Western White Pine	Pinus monticola													X
43	Lodgepole Pine	Pinus murrayana	X	X	X				X						
44	Rattlesnake Plantain	Plantago sp.									X	X	X	X	
45	Aspen	Populus tremuloides		X	X			X							
46	Black Cottonwood	Populus trichocarpa		X	X										
47	Yellow Cinquefoil	Potentilla glandulosa			X										
48	Bitter Cherry	Prunus emarginata							X	X	X	X	X	X	
49	Pinedrops	Pterospora androw						X							X
50	Bitterbrush	Purshia tridentata				X	X	X	X		X	X			
51	Huckleberry Oak	Quercus vaccinifolia						X		X			X	X	
52	Buttercup	Ranunculus calif.			X										
53	Sierra Currant	Ribes nevadense	X	X	X		X	X	X	X	X	X	X		X
54	Sierra Gooseberry	Ribes roezlii								X				X	X
55	Calif. Wild Rose	Rosa sp.	X	X	X	X									
56	Thimbleberry	Rubus parviflorus								X	X	X		X	X
57	Willow	Salix sp.	X	X	X				X						
58	Elderberry	Sambucus caerulea													X
59	Snowplant	Sarcodes sanguinea						X			X	X	X	X	X
60	Groundsel	Senecio triangularis			X										
61	Wild Hollyhock	Sidalcea reptans				X									
62	Spiked Mallow	Sidalcea spicata	X	X	X										
63	Meadow Goldenrod	Solidago elongata	X	X	X										
64	Swamp Whiteheads	Sphenosciadium sp.			X										
65	Snowberry	Symphoricarpos mollis			X		X	X		X	X	X	X		
66	Danelion	Taraxacum sp.	X	X	X	X									
67	Clover	Trifolium sp.	X	X	X										
68	Mule Ears	Wyethia mollis	X	X	X	X	X	X	X		X	X	X	X	
69	Death Camas	Zigadensus venen.			X										
70	Various Grasses		X	X	X	X	X								
71	Corn Lily	Veratrum calif.	X		X										
72	Sulphur Flower	Eriogonum umbellatum				X									
73	Fireweed	Epilobium angustifolium				X									

- Tobacco Brush will seed itself naturally into the disturbed areas but should not be permitted to immediately take control around the units.

- Valley Condominiums

  - Plants should be Willow, Alder, Dogwood, Aspen, and Black Cottonwood.
  - Willow and Alder may be pruned to maintain shrub forms and reduce excessive water loss in the soil.
  - A grass mix favoring clover should be seeded in the wet areas and the remaining areas seeded with regular grass-legume mix.
  - Large groups of Aspen should be thinned and all decayed and nonvigorous trees removed.
  - Invading pine and fir should be removed in order to preserve the meadow quality of the existing mosaic.
  - No track or heavy equipment should be used in or traverse the areas.
  - Slash and heavy brush should be removed to reduce fire hazard, enhance the appearance, and increase the recreational use value.

2. Residential Lots

- General Recommendations

  - Jeffrey Pine infected with Limb Rust (Cronartuim filamentosum) should be removed.
  - White Fir infected with mistletoe should be removed.
  - Slash, dead, or haggard trees should be removed. Small rubber tired vehicles should be used for this operation and no dragging over the surface should occur. All material should be lifted and carried off site.
  - Existing trees may be pruned or removed in small numbers to improve appearance and views.
  - Ground cover should be reestablished as soon as possible after disturbance to reduce dust.
  - Pine-Fir subunits should be planted with Jeffrey Pine, White Fir, Squaw Carpet, and Newberry Penstemon with grass-legume mix plus Mule Ears and Brewers Lupine.
  - Fir-Pine subunit should be planted with Jeffrey Pine, White Fir, Pinemat Manzanita, and Newberry Penstemon with grass-legume mix plus Mules Ears and Brewers Lupine.

3. Village Center

- General Recommendations

  The area should be planted and managed for heavy impact and use. Some water may be necessary for irrigation.

- Red Fir, White Fir, and Jeffrey Pine should be planted.
- Consideration should be given to moving several larger trees for more immediate impact.
- Black Cottonwood, Aspen, Willow, Alder, Dogwood, and Thimbleberry can all be used here but will require irrigation.
- Ground cover should be Squaw Carpet, Pinemat Manzanita, and Newberry Penstemon.
- Grass-legume mixture with fertilizer should be applied to disturbed surfaces. For areas to be maintained as grass, a clover mix should be used but will require irrigation.

4. Living Area Recommendations

- Concept

  - Maximize the use of native materials for amenity and utility purposes to combat undesirable noise, to create shelter from wind or visual screening, create shade, and regulate circulation with barriers. Hardwoods and softwoods should be kept as a mixture, where possible, to take advantage of summer and winter conditions (shade, snow).

- General Recommendations

  - Rapid growing hardwood species, such as Black Cottonwood and Aspen, should be used on moist sites or where water is available for an initial establishment period of 3 years. Both species are readily propagated in large numbers.
  - Pines and firs representative of each vegetation zone should be planted to replace trees lost in development. The maintenance of 30 to 40 percent crown cover density is important to preserve the character of a "forest environment."
  - Barrier plants for visual screening, wind breaks, and circulation control should be Alder, Mountain Dogwood, and Aspen in moist areas, and Tobacco Brush and Serviceberry where water is not available.
  - White Fir, Red Fir, and Tobacco Brush have dense foliage and should be the most useful for noise control.
  - Singeing of trees when burning slash, burn piles will cause browning of needles which will not drop for 2 to 3 years. Therefore, burn piles should be established on road rights-of-way, building and ski terminal sites, and as far from surrounding vegetation as possible. Burning should occur only after a good fall of snow since the snow will protect the surrounding vegetation.

5. Road Rights-of-Way

- General Recommendations

  - Cuts and fills should be covered with 6 inches of topsoil as previously recommended.
  - When natural revegetation does not occur, a grass-legume seed mixture with Mule Ears and fertilizer mix added should be applied immediately prior to the first snow fall. No watering should be done in the fall due to possibility of false germination and resultant loss of cover.
  - Squaw Carpet and Newberry Penstemon should be used to an elevation of 1,900 meters.
  - Pinemat Manzanita and Newberry Penstemon should be used over 1,900 meters elevation.
  - Other species should be used in accordance with the subunit in which the cut occurs.
  - Considerations of safety, design, aesthetics, pedestrian crossings, and snow removal must be made for each specific case.

6. Trails and Paths

- Concept

  - Generally reduce impact to a minimum while aiding safety, usability, and amenities.

- General Recommendations

  - Trails not in the immediate development area (or not of first importance for general circulation) should be marked and layered with fir bark or moved annually to prevent permanent compaction and subsequent erosion channels.
  - All paths of primary importance in the development areas should be hard surfaced and clearly marked to permit snow clearance.
  - Disturbed areas should be treated in the same way as for cuts and fills in road rights-of-way.
  - Plant materials should be those most resistant to impact, hardy, and prostrate. Such plants (as selected according to the subunit through which the trail passes) include: Snowberry, Thimbleberry, Serviceberry, Newberry Penstemon, Pinemat Manzanita, and Squaw Carpet.
  - A self-guided nature trail could be planned to pass through the different ecological subunits with interpretive information along the trail.

7. Ski Slopes

- Concept

    - Ski runs are areas of bare or partially bare ground which should be vegetated to stabilize the slopes, reduce soil erosion, maintain the visual character, and minimize reradiation and early snowmelt in the spring.

- General Recommendations

    - Pinemat Manzanita, Newberry Penstemon, Tobacco Brush, and Squaw Carpet should be planted on the ski trails as soon as possible.
    - Seeding with the same mix as for road cuts should be used prior to snowfall. Seeds of shrubs recommended above should be added when available.
    - Green Leaf Manzanita should not be used and should be eliminated when possible since it does not lie flat with snow cover. The plant will stick through low snow cover, hasten springmelt, and present a hazard to skiing.

8. Golf Course

- Concept

    - The detailed design of the golf course should adhere to the natural topography as much as possible in order to retain mature trees. Nevertheless, the golf course development will threaten the Jeffrey Pine-Sage-Mule Ears community due to the grading and irrigation.

- General Recommendations

    - A drainage reservoir should be engineered to capture the irrigation water return flows. Fertilizer and other runoff would seriously alter the creek waters and valuable water would be wasted without such a reservoir.
    - Since irrigation water will be available, Aspen, Cottonwood, and Jeffrey Pine should be planted.
    - White Fir should not be planted.
    - A clover mixture should be used within sprinkling distance of the groomed fairways.

It was estimated that the total disturbed area requiring revegetation following construction of the entire planned Northstar development would be 65 hectares or about 6.3 percent of the total 1,036 hectares of West Martis Creek Northstar property.

The total number of plants estimated to be required to revegetate this area was as follows:

1.	Ground Covers and Shrubs	$152,410
2.	Hardwood Trees	11,280
3.	Conifer Trees	22,560
	Total	$186,250

In addition, it was estimated that approximately one-half of the disturbed 65 hectares would also require hydromulching with grasses and native seeds.

E. Criteria Summary

The planning process conducted prior to the construction of Northstar-At-Tahoe was extensive. Many of the problems plaguing other poorly designed developments, both past and present, were avoided at Northstar. Although costly at first, the type of predevelopment planning conducted at Northstar is likely to be relatively inexpensive in the long run. As will be discussed in later sections of this report, treatment of erosion and sediment control pollution problems after the fact is extremely expensive. In addition, the cleanup of erosion and sediment control pollution problems, once a development is constructed, are many times much less effective than if adequate precautions had been taken initially.

Dr. Paul J. Zinke, the consulting ecologist to the Northstar development, summarized the attributes of the Northstar development planning in a 1971 report. Those points pertaining to erosion and sediment control made by Dr. Zinke are as follows (13):

1. There has been an awareness of the value of the landscape and its natural setting throughout the development of the project. This awareness is an attempt to set economic and ecological objectives on a parallel and reinforcing direction.

2. Logging operations for timber harvest in the 1950's were planned to maintain a landscape value that was based on the natural integrity of a forest landscape. Logging road locations and designs were such as to keep erosion to a minimum. Logging roads generally conform to the contours of the slopes. There was no clear cutting; only thinning operations allowed.

3. Initial development potentials for the property were recognized as being due to outdoor recreation and a need to maintain a favorable environment established as an economic goal. The intent was to develop Northstar for a market that would prefer a developed property that is based on a sound environmental ecological basis.

4. The maintenance of year-round facilities at Trimont was recognized as requiring planning for winter as well as summer ecological impact. Clear waters and wooded slopes were recognized as being principal environmental attributes of the area.

5. The unique qualities and ecological processes of the landscape are primary determinants of the proper form of development in the Northstar area. There is evidence of awareness that the complex landscape processes which brought about the present environment will also ensure its continued stability if not drastically altered. For purposes of ecological study, vegetation, soil, geology, topography, and hydrology, all have received separate and complete analysis.

6. Slope criteria were recognized as being of primary concern in determining developable area. In general, areas of greater than 15 percent slope were considered inappropriate. Occasional development of areas from 15 to 25 percent was considered possible only in exceptional situations.

7. Hydrologic and drainage factors were evaluated for the property. A water balance was prepared, identification of stream types was made, and the characteristics of subsurface aquifers were identified.

8. The property north of Lake Tahoe and south of Martis has an ecological integrity that is based on a combination of geology and resulting soils, climate, topography, and finally the vegetation that is adapted to these. The critique of the planning for the Northstar property was based upon the degree to which the ecological integrity of the site would be affected by proposed development.

9 Soil criteria for development were based upon a soil-type map compiled from an existing soil map for the Tahoe Basin, from the geology map for the area, and from field reconnaissance of the actual area. Any limitations or disadvantages for development from the soil standpoint were noted. Areas that would not sustain development were noted as being unsatisfactory.

10. Conflicts between preliminary development plans and ecological integrity of the area were identified. Adjustments were made to arrive at a final plan respecting the integrity of the site. Constraints were applied to the development based upon the vegetation, soil, slope geology, snowfall, hydrology, and visual impact. The primary constraints on development to protect the ecological integrity were based on slope and drainage.

11. Computerized map printout and suitability models have been made for the development which takes into account ecological criteria. The computerized maps are on a one-acre basis, and there are individual maps for each of the following ecological criteria. For vegetation type; conifer age class, vegetation density, water types on the site, snow depth, sun intensity maps for winter months, average annual sun intensity, visual analysis model, topographic analysis, aspect and exposure map, slope map, ski slope suitability map, land development suitability model, and ski slope suitability map.

12. The beginning of detailed planning for the siting of roads, buildings, and other improvements in the Martis Valley area has been marked by a continuous series of discussions pinpointing and dealing with ecological opportunities of the site.

13. Ski area terrain at Northstar is less steep than other ski areas. The ecological impact at the Northstar development, insofar as erosion is concerned, will be less than other ski developments due to the lesser steepness of slopes. Ski areas are being developed mainly for intermediate skiers. Continually, emphasis was placed on the location of ski areas on smooth, rock-free terrain having enough soil so low cover can become established for erosion control.

14. The siting of amenities, drainage works, power lines, and other development features in the Northstar Basin area has been done in such a way that the alteration of natural environment in the area will be at a minimum.

15. There is every indication that the concern for the environment represented by these measures will continue in the future.

The last point is of extreme importance. The best planning principles could all be for naught if the continuing responsibility for the impact of the development was not properly assumed. In the case of Northstar, the original developers maintain a continuing interest in the development. Although a small portion of the development is sold to private ownership (less than 8 percent), the vast majority of Northstar will continue to be owned and operated by a single responsible entity (in addition to the services provided by the county). The myriad of potential problems, which were recognized in the planning process, must continue to be addressed during the continued expansion and operation of Northstar-At-Tahoe; thus, if the concern exhibited in the planning is continued through the construction and maintenance phases, there is considerable reason to believe that a development, such as Northstar, would have minimal, if not negligible, adverse impact upon water quality and the environment.

SECTION V

NORTHSTAR-AT-TAHOE: A WELL PLANNED AND CONSTRUCTED RESIDENTIAL-RECREATIONAL DEVELOPMENT

To a considerable degree, the actual construction of the Northstar development was closely patterned after concepts developed in the planning stages. The unique commitment of Northstar's developers to thorough planning and careful construction has led to a well conceived development which has minimized any adverse environmental impacts. Compared to most other past and present developments of the Lake Tahoe vicinity, Northstar-At-Tahoe is one of the best examples of a well planned and constructed residential-recreational complex. As documented in Section VII of this report, erosion, as measured by suspended sediment transport in West Martis Creek, was held to about a one-fold increase over very low background levels. Such an accomplishment would be possible only through the most careful planning and construction practices.

The ultimate Northstar plan calls for the construction of 132 hectares of ski runs, a 68 hectare golf course, 585 single-family 0.1 hectare residential lots, 3,115 condominium units, a recreation center, a 1.2 hectare village commercial center, 10 hectares of utility and maintenance facilities and 48 hectare of roadways and parking lots. However, as of 1977, less than half of the originally planned development was constructed. Additional units are to be added as future markets conditions dictate. Only the construction of ski runs is essentially complete. At present only 6 of the 14 originally planned ski lifts have been constructed and only one-half of the originally planned 18 hole golf course has been completed. Of the housing units, about 55 percent of the residential lots have been subdivided while only 25 percent of the potential condominium units are built or under construction. Table V-1 describes the engineering, construction, and sales sequence of the presently existing Northstar development units.

A. The Ski Area

Only in the most intense rainstorms (greater than 1.5 centimeters per hour) and during rapid spring snowmelt is there any significant sediment discharge to West Martis Creek from the ski area. The primary reason for this is the fact that the watershed and terrain chosen is highly suitable for the development of a ski area. The natural terrain is gently sloping and the high natural percolation rate of the native soils prevents significant overland flow. Hence, the potential for significant erosion problems was reduced simply by proper site selection. Nonetheless, erosion

TABLE V-1

NORTHSTAR DEVELOPMENT SCHEDULE

Unit	Engineering	Construction	Sales
. Comdominiums	1971-72	1972-74	1972-present
. Homesites	1971-73	1972-73	1973-present
. Commercial Area	1972	1972-73	1973-present
. Ski Area	1970	1971-74	1973-present
. Recreation Center	1972-73	1973-74	1973-present
. Stables	1973	1974	1973-present
. Golf Course	1971-76	1972-77	1973-present
. Utilities	1971-72	1971-73	N/A

problems would have appeared had not careful construction practices been implemented in the development of the ski area.

In most instances ski runs were cut on less than 3:1 (horizontal to vertical) slopes and in diagonal patterns at an angle to the fall line. This prevented the accumulation and concentration of runoff in disturbed areas. Rather, any storm and snowmelt runoff from areas disturbed for ski run construction is discharged to and "filtered" through, undisturbed buffer zones. On the steeper ski runs which could not be sloped diagonally across the fall line and natural drainages, artificial water bars and diversion structures were constructed. These structures effectively divert runoff to adjacent undisturbed terrain, yet only create gentle rolls on the ski slopes which do not pose a hazard to skiers.

Where possible, natural low-lying native vegetation was left undisturbed to provide soil stabilization. This was accomplished, in part, by the almost exclusive use of rubber-tired vehicles for tree removal and slash disposal. Those areas where native low-lying vegetation was heavily disturbed or naturally less dense were reseeded artificially, the seed mixtures which were employed contained rhizominous wheatgrasses and legumes and were irrigated where necessary.

On areas which are clear cut for ski runs, remaining tree stumps can pose a hazard to skiing. Traditionally, the method used to mitigate this hazard is the use of explosives or bulldozers to remove dangerous stump material. This method usually results in considerable soil disturbance and can lead to the channelization of storms and snowmelt runoff. To avoid this problem at Northstar, all stumps were "flush cut" where possible. However, in many cases, flush cut tree stumps left in place had a tendency to "reappear", due to localized erosion or cause rapid melting of snow over the stump, resulting in hazards to skiers. To alleviate this problem at Northstar, without resorting to explosives or heavy equipment, problem stumps were first split with special equipment, with the pieces then pulled out using light tractors. This

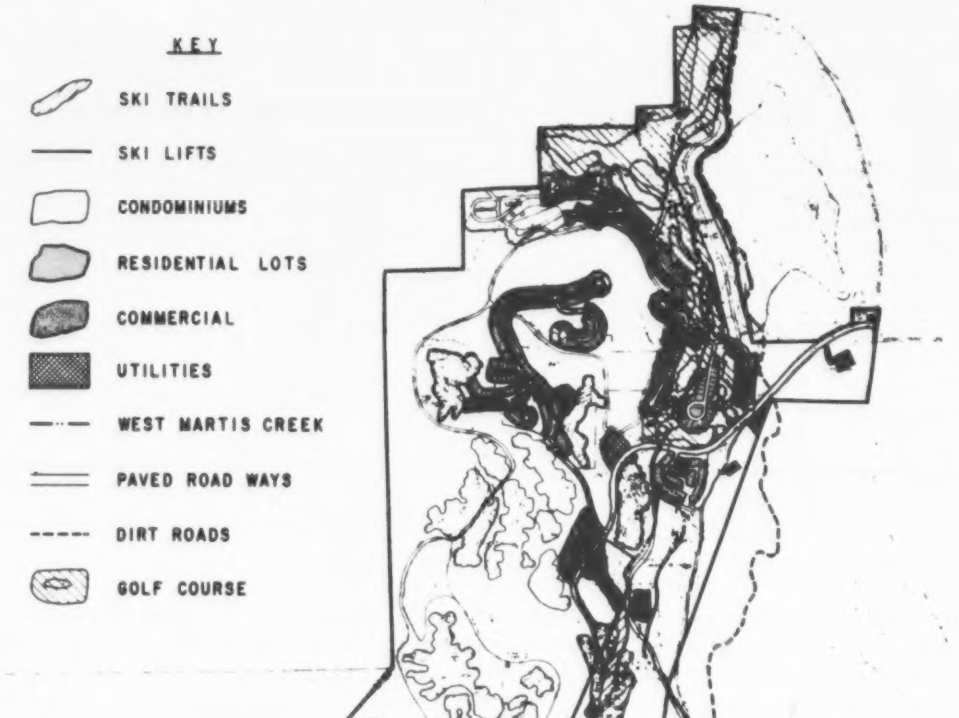

KEY
SKI TRAILS
SKI LIFTS
CONDOMINIUMS
RESIDENTIAL LOTS
COMMERCIAL
UTILITIES
WEST MARTIS CREEK
PAVED ROAD WAYS
DIRT ROADS
GOLF COURSE
0
1/2
1
KILOMETERS

FIGURE V-1.
EXISTING LAND USE DEVELOPMENT AT NORTHSTAR AS OF JULY, 1977.

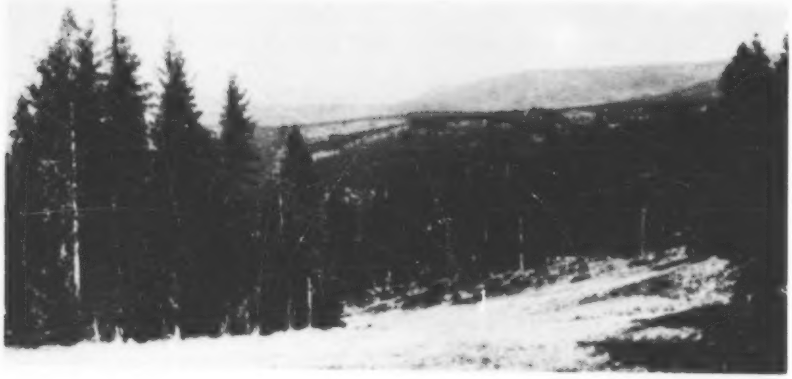


Figure V-2. Well revegetated ski run at Northstar using rhizomimous wheatgrasses

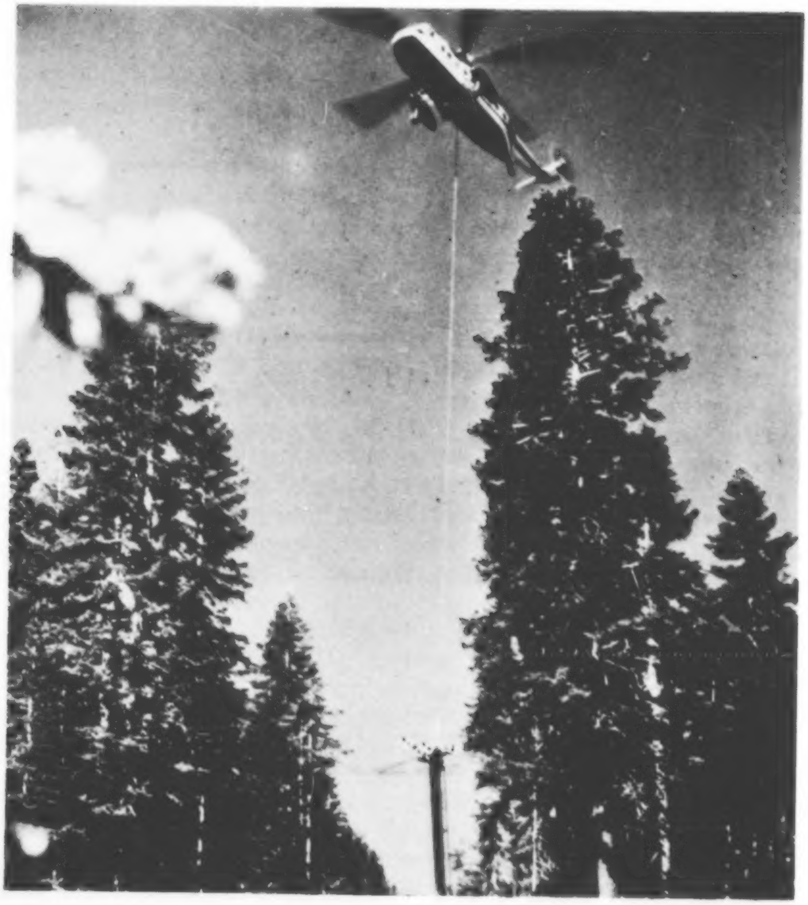


Figure V-3. Helicopter installation of ski lift towers reduces ground disturbances at Northstar

procedure substantially reduced the amount of disturbed soil yet provided an easier-to-maintain, obstacle-free ski run.

In most instances, ski lift towers were installed by rubber-tired overland vehicles. Although some disruption occurred, it was not extensive due to the usually gentle terrain in which they were installed. In order to prevent extensive disruption in critical areas, helicopter construction was employed for the erection of a ski lifts which traverses steeper, more erosion prone terrain. By eliminating all heavy equipment, substantial disruption of the natural terrain by vehicular traffic was prevented.

B. Street and Parking Lot Construction

In most developments, nonrevegetated and oversteepened cut and fill slopes associated with road and parking lot construction are the primary source of eroded sediment material contributing to water quality problems. Improperly controlled runoff from the impervious road surfaces frequently aggravates the problem. Although the majority of excess sediment transport at Northstar appears to also derive from these sources, the problem is much less severe than frequently encountered in other developments.

Considerable attention has been paid to the reestablishment of vegetation on the cuts and fills adjacent to the roadways and parking lots at Northstar. Although the developer did not strictly employ all of the recommendations made in the "Northstar Planting and Revegetation Management Program" described in Section IV, considerable effort was made in reestablishing vegetation on disturbed slopes. The primary vehicle to accomplish this was the practice of topsoiling. Prior to the excavation for a roadbed or parking lot site, the upper 0.25 to 0.50 meters of natural topsoil was stripped and stockpiled in a adjacent storage area. Care was taken to insure that the topsoil material would not be stockpiled in areas subject to concentrated storm or snowmelt runoff or otherwise potentially threaten the water quality of West Martis Creek. Once the roadway or parking lot was fully excavated, the topsoil was replaced on the adjacent exposed cut and fill slopes. In most cases, the cuts were no steeper than 1½:1 (horizontal to vertical) and the fill slopes no steeper than 2:1. In all cases, soil excavated from one of the vegetation subunits identified in the "Northstar Planting and Revegetation Management Program" was replaced in the same subunit. This insured that propagation of native plants from seeds contained in the topsoil would not be in conflict with the natural vegetation of each subunit. Furthermore, native seeds had a better opportunity to germinate and survive in zones of their preferred habitat. Approximately 7,800 cubic meters of topsoil were required to cover 4.7 hectares of disturbed slopes at Northstar. The average unit cost of the complete topsoiling operation was $4 per cubic meter.

Generally, reestablishing native vegetation by stockpiling was very successful. In a few instances, slopes which were too steep to be properly topsoiled were left bare. In other instances, the topsoil

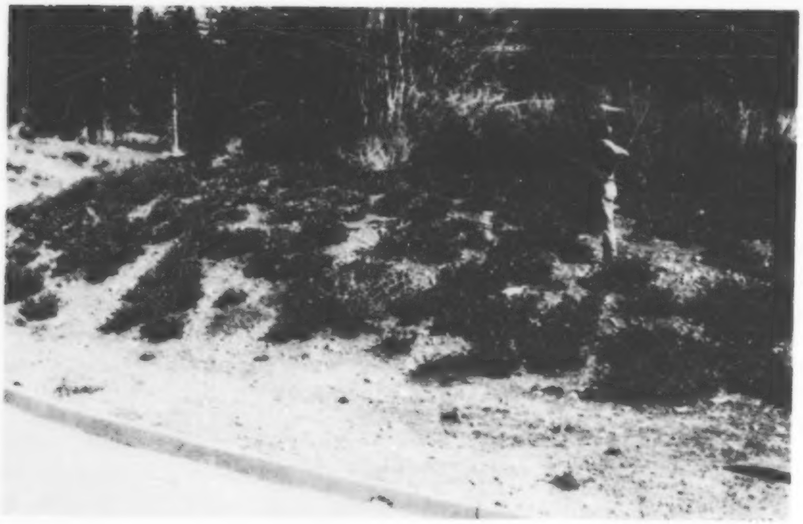


Figure V-4. Vegetation from native seed in topsoiled area at Northstar after four years

site was too dry or there was insufficient seed material to generate satisfactory growth. In these cases, various planting techniques were demonstrated by the Soil Conservation Service (SCS) under a cooperative agreement with the Northstar developers. Demonstrated methods included the following:

1. Hydromulching of slopes with various grass and legume seed mixture.
2. The planting of native and nonnative shrub seedlings.

The location and description of these demonstration seedings and plantings are included in Appendix B.

Considerable effort was also expanded on the adequate control of runoff and drainage from impervious road and parking lot surfaces. Where possible, runoff is collected from impervious surfaces in small amounts and discharged at numerous locations to undisturbed areas where the native soils are sufficiently pervious to allow complete percolation. In areas where complete percolation is limited by local soil conditions or the amount of runoff is extremely high, drainage waters are collected in nonerodible rock-lined drainage swails and discharged directly to West Martis Creek. The former method of percolation is far superior. The erosion control project staff was unable to locate any discharges of this nature which exceeded the capacity of the soil or caused erosion problems. In those locations where discharges to undisturbed areas were used, the drainage waters would have to travel overland for 100 meters through heavily vegetated terrain before reaching downslope disturbances.

Direct discharges to West Martis Creek, whenever monitored, clearly resulted in lower stream water quality. As documented in Section VII, however, these discharges do not appear to have harmed the aquatic life of West Martis Creek. In most instances, the sediment discharged to the creek in this manner was not eroded from the rock-lined drainage swales but was of some other origin. Typically, sediments were transported to the swales from eroding slopes and from winter road sand. Without settling and/or percolation facilities, suspended sediments, once eroded, are readily transported to West Martis Creek by the artificial drainage swales at Northstar.

C. Condominiums, Village Center, and Homesite Construction

The primary reason potential erosion and sedimentation problems were held to a minimum at Northstar was that the majority of the development was confined to the portions of the West Martis Creek watershed which were most amenable to development. Ideally, as identified by the Northstar planners, this meant restricting construction of commercial and residential buildings to areas with less than 15 percent natural slope or with insensitive vegetation types. However, the portion of the property which conformed to this criteria was fairly limited. Thus, the areas which were actually developed, or are planned for development, extend somewhat beyond the area defined as "developable" or "developable with forest management controls" (see Figure III-9). A summary of development confinement to areas defined as ideally developable is presented in Table V-2. As indicated in the table, fully 30 percent of the existing development (excluding the ski area, golf course, and roadways) are beyond the boundaries of what was originally defined "developable". However, in all cases, building construction has not taken place on terrain steeper than 25 percent, with the vast majority occurring on terrain less than 20 percent grade. Based on the water quality monitoring program discussed in Section VII, only minor and isolated erosion and sediment control problems have resulted from extending development to these areas. The principle sources of eroded sediments are the larger and frequently oversteepened cut slopes which are required when construction occurs on steeper terrain. Where possible, the excavated cuts and fills were revegetated by topsoiling, however, the steepest slopes were frequently left unvegetated and highly erodible.

An additional erosion problem associated with the construction of condominium, homesites, and commercial buildings is the undergrounding of utilities, such as water distribution lines, trunk sewers, and electric and cable TV service. At Northstar these operations were usually performed conjunctively with construction of roadways and building units. Occasionslly, the undergrounding of utilities necessitated the excavation of easements through steeply sloping, previously undisturbed terrain. To stabilize these areas satisfactorily, water bars and erosion checks were placed across the disturbed easements to drain runoff to adjacent

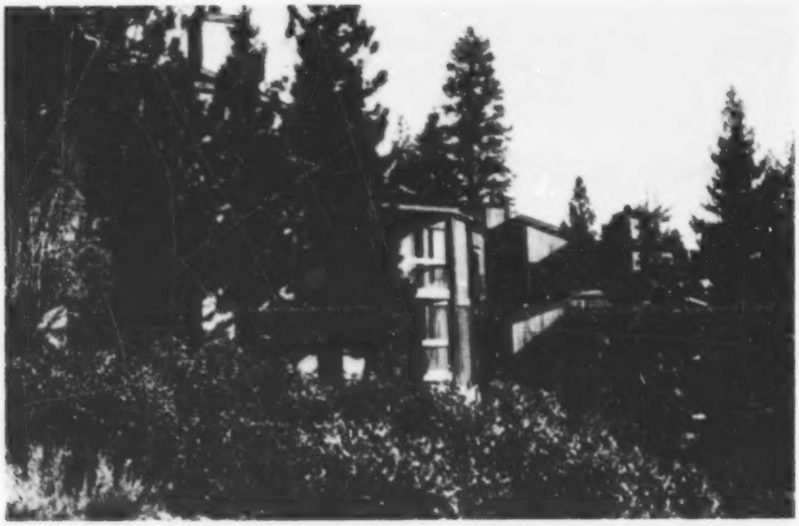


Figure V-5. Condominiums at Northstar situated in an area of minimum environmental impact with little disturbance to surrounding vegetation.

Figure V-6. Discharge of condominium parking lot runoff to downslope undisturbed area at Northstar.

TABLE V-2

DEVELOPED AREAS AND PERCENT OF
DEVELOPMENT UNIT TYPE IN
"DEVELOPABLE" AREAS[A/][B/]

Development Unit Type	1977 Land Use		ULTIMATE Land Use Plan	
	Total Area (hectares)	% "Developable"	Total Area (hectares)	% "Developable"
Commercial	9.73	38%	15.52	58%
Utilities	5.97	31%	6.52	23%
Condominiums	19.56	71%	79.09	66%
Residential Lots	47.66	82%	86.33	80%
TOTAL	83.92	70%	187.46	66%

[A/] "DEVELOPABLE" means areas with less than 15% slopes and vegetation which can sustain development with "forest management controls".

[B/] AREAS are those areas defined by unit boundaries, not the areas which are covered by just impermeable surfaces.

undisturbed areas. Along with the replacement of native seed-rich topsoil, the erosion checks greatly facilitated the rapid reestablishment of vegetation.

For the most part, extensive erosion control facilities were not required for the Northstar condominiums, village center, and homesites. This is primarily due to the planning expenditures made in centering these portions of the development in areas most amenable to construction activities. The total cost of the basic improvements for the Northstar condominium, village center, and homesite units was $4,800,000. This included the cost of roadways, parking lots, utilities, and other "prebuilding" development amenities. Of this total amount only $79,584 or 1.66 percent, was spent on special erosion control methods. Among these special erosion control methods were the following:

1. Check dams and erosion baffles.
2. Rock riprap energy dissipators.
3. Rock riprap 'V' ditches.
4. Rock riprap drainage channels.
5. Rock riprap slope protection.
6. Top soil removal, storage, and replacement.

Not included with these "special" erosion control methods were the cost of what may be considered normal or standard structures such as A-C curbs, dikes and gutters, drainage culverts, drop inlets, and perforated groundwater collection pipes. The total cost of all the above facilities, including special erosion control, amounted to $510,866 or less than 11 percent of the total "prebuilding" development cost.

D. Remaining Problems

In spite of the considerable effort taken by the Northstar planners and developers, certain erosion and sedimentation related problems were created by the development. In most cases these remaining pollution sources were identified as potential problems during the planning of Northstar. Although recognized in the planning phase, adequate mitigation measures were not immediately carried through to the construction and maintenance phases. As a result the water quality monitoring program, described in Section VII of this report, has documented an estimated one-fold increase in the sediment yield of the West Martis Creek watershed. In addition, a water quality computer simulation program was used to identify the specific location and relative contribution of suspended sediments being discharged by various portions of the development.

Five areas were documented as the significant areas of erosion affecting the water quality of West Martis Creek. If these remaining problem sources were corrected within Northstar, post-development erosion and sediment transport levels would be reduced to very low pre-development levels in all but the most intense and severe storm runoff events. Figure V-7 indicates the location of major remaining sediment and erosion problems identified at Northstar.

1. Unrevegatated Oversteepened Slopes

These remaining problem areas were mainly centered around the west village center parking area, the wastewater treatment plant, and Northstar Drive. The main source of sediments eroded from oversteepened slopes was from the west village parking lot. Here, drainage from the almost 0.75 hectares of disturbed slopes reached suspended sediment levels of 7560 ppm. The average concentration recorded in 19 samples taken during rainstorms and snowmelt runoff events was 1,732 ppm.

In many cases, the slopes adjacent to the west parking lot are 1.5:1 (horizontal to vertical) or steeper. These slopes are generally too steep for the technique of topsoiling. No other attempt was made to revegetate these slopes by the Northstar developers. The apparent reason for these large, unstable cut slopes was that if they had been cut at a less severe angle, they would have produced longer, more visible scars. In addition, there were no other areas within the development which were better suited for the construction of a parking lot facility necessary for access to the ski area. Similar to the cut slopes for the parking lot, Large cut slopes were also created by the construction of the wastewater

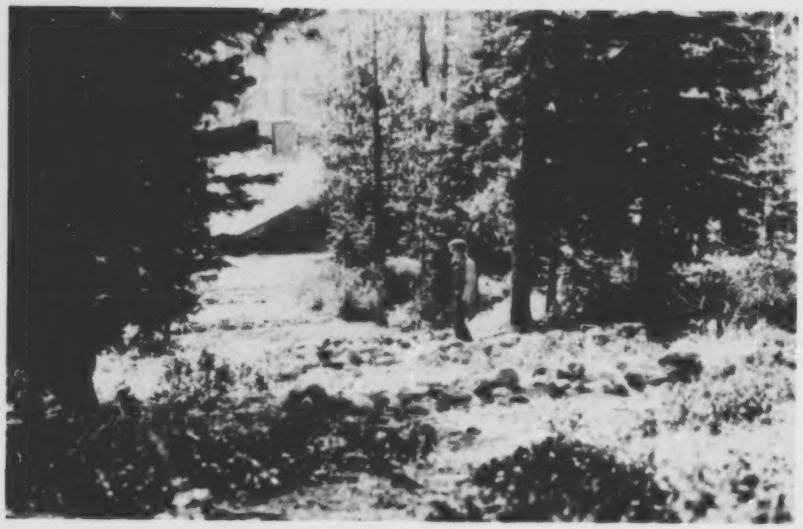


Figure V-7. Rock rip-rapped check dams protecting an area at Northstar disturbed by the underground placement of utilities

treatment plant. In both cases, the cut slopes intersected semipermeable hardpan layers supporting perched water tables during spring snowmelt conditions. The hardpan layers are the remnants of buried Pliocene stream beds.

Northstar Drive exhibited erosion problems similar to, but less significant than, the parking lot and wastewater treatment plant cuts. In this case, no groundwater table was pierced during road construction activity, so the problem consists of road sand and eroded sediments from an unvegetated fill slope carvied by storm and snowmelt runoff. Differences in suspended solid concentrations of up to 100 ppm have been measured in West Martis Creek from above to below the road's crossing for the stream.

2. Urban Runoff

The principal source of measureable urban runoff is from the village center commercial area and adjacent condominium units. To a large degree, suspended sediments contained in urban runoff originates from the oversteeped slopes described above. However, a large part is apparently contributed by winter road sand and dirt transported to the parking lot areas by vehicular traffic. Accumulated urban runoff at Northstar is discharged to West Martis Creek at two major points near the confluence of the West and East Forks

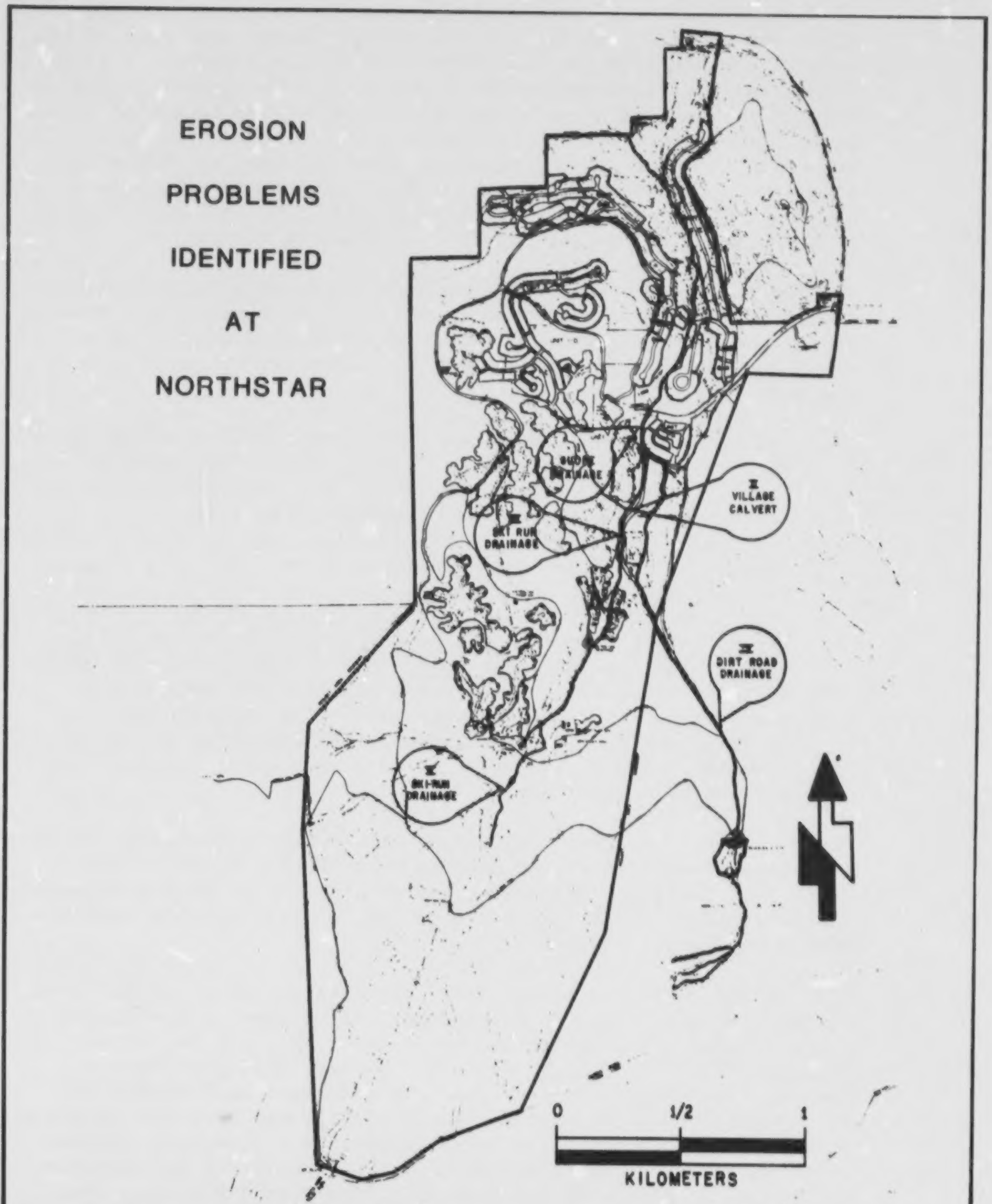

EROSION
PROBLEMS
IDENTIFIED
AT
NORTHSTAR
I
SLOPE DRAINAGE
II
VILLAGE CALVERT
III
SKI RUN DRAINAGE
IV
DIRT ROAD DRAINAGE
V
SKI-RUN DRAINAGE
0
1/2
1
KILOMETERS

FIGURE V-8.
EROSION PROBLEMS IDENTIFIED AT NORTHSTAR, 1974-1976.

of West Martis Creek. The "village culvert" discharges accumulated storm and snowmelt runoff from the village center (and most of the parking lot area) to the West Fork above the confluence. A rock-lined-drainage ditch discharges accumulated storm runoff from a portion of the parking lot, condominium units, and Northstar Drive, about 100 meters below the confluence. The maximum recorded suspended sediment concentration recorded at these two sites were 1,188 ppm and 5,500 ppm for the village culvert and rock-lined-drainage ditch, respectively. The average of 50 samples collected at these two sites during runoff conditions is 394 ppm.

The potential for urban runoff problems to develop at the village culvert was clearly recognized in the planning process at Northstar. As part of the environmental impact report prepared prior to the development of the village center, the following recommendation was made (11):

> "In order to insure compliance with the State of California's Porter-Cologne Water Quality Control Act and Northstar's internal quality control standards, it is recommended that an adequate catch mechanism and energy dissipator such as "bubbleup" catchment basin and sediment pond or other similar devices be installed and serviced regularly in order to provide for settlement of suspended sediment prior to outfall into Martis Creek. There should be no significant deviation beyond natural background levels of turbidity and total suspended dissolved sediment load. The construction of a catchment mechanism and sedimentation provision as recommended above should slow the drainage water to a velocity equal to or less than Martis Creek and will minimize the cutting and carrying power of the water as well as the size of particles carried by Martis Creek."

However, there was never any suspended sediment settling or catchment basin installed as recommended. Had such a facility been adequately designed, installed, and maintained, suspended sediment discharge to West Martis Creek from the "village culvert" would have been greatly reduced.

The village culvert drainage area possesses two factors that tend to increase its effect on the stream. First, the parking lots drain to drop inlets which transport the flow directly to the stream through the village culvert. Second, during the winter months, a moderate amount of sand and salt used on highways and at the entrance to Northstar is tracked to these lots and deposited by warm dripping cars. This deposition is not a serious problem under most winter conditions because the majority of the sediment is removed from driving surfaces by periodic snow plowing. However, during periods of winter thawing, significant levels of salts and suspended solids appear to be discharged from these surfaces. This discharge, in combination with the erosion from the cuts, appears to have significant effect on the water quality of the lower

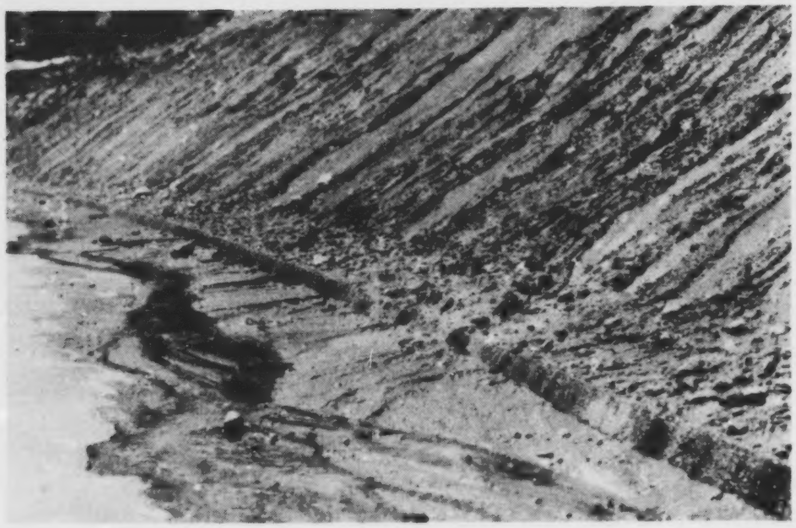


Figure V-9. Oversteepened and eroding cut slope adjacent to the parking lot at Northstar in the spring of 1975

watershed. For example, water sampling on February 19, 1975, established the village culvert as the sole source of pollution for the West Fork of West Martis. Its flow of 14 liters per second with a concentration of suspended sediments (S. S.) of 1,072 ppm, turbidity reaching 330 FTU, and a concentration of total dissolved solids (TDS) of over 500 ppm adversely affected stream water quality to the confluence of East and West Forks of Martis Creek (S. S. = 1240 ppm; TDS = 170 ppm). These conditions to persist to reduced degree for some distance further downstream.

3. Unvegetated Ski Run and Uncontrolled Drainage

The transport lift area is located just above the village center. For the period of May 9 to 22, 1975, water containing 3,200 to 6,090 ppm suspended solids concentration flowed across this skiing thoroughfare and entered the West Fork of West Martis Creek near the bridge to the recreation complex. The problem was the result of a drainage culvert from a condominium unit depositing its flow on an unrevegetated ski run and transport lift area. This flow created up to 0.5-meter deep gullies near its source. There was also up to 10 centimeters of sheet erosion on the open slopes and up to 0.25 meter deep gullies formed near the confluence with the West Fork. This problem was further compounded by heavy vehicular and ski traffic during the spring snowmelt period which had a tendency to further disturb the unrevegetated terrain.

4. Heavily Travelled Dirt Road Drainage

The only dirt road at Northstar which receives heavy traffic during runoff events is the access road to the ski maintenance area. During periods of heavy spring snowmelt and runoff, road drainage, extremely high in suspended sediments, enters the East Fork of West Martis Creek at the point of road crossing. The creek crossing is located at a low point where the road slopes down to the creek from both directions. Although streamflow is directed under the roadway, drainage from snowmelt collects at the low points and enters the creek. Suspended sediment concentrations as high as 4,169 ppm have been detected in the road drainage. During spring snowmelt conditions, the instream suspended sediment concentration of the East Fork has gone from near zero to 100 ppm.

Were it not for the vehicular traffic during the springtime, this dirt road would not pose much of a problem. Maintenance vehicles and other traffic clearly aggravate the situation by disrupting the road surface causing the area to become extremely muddy. The ultimate solution would be to pave the road surface to eliminate the disruption caused by vehicular traffic. Also required is adequate drainage of storm flow from the road surface to the East Fork. Because of this single suspended sediment problem source in the East Fork the yearly suspended sediment yield of this portion of the West Martis watershed was increased approximately 3 to 4 times above natural background levels.

5. Uncontrolled Drainage at the Base of the Ski Bowl

These problems located high in the watershed at the base of the ski area are only noticeable during periods of extremely high storms or snowmelt runoff. Because of the design and layout of the ski bowl, erosion problems have been held to a minimum. Except during high runoff conditions, surface runoff is almost completely percolated to groundwater. At the base of the ski area, the groundwater is tapped by means of a perforated pipe collection system to serve as a source of domestic water supply. With the exception of some springs and the water system bypass, very little surface flow appears at the base of the ski area except during extremely high runoff conditions. At these times, disturbed areas on unstabilized drainage channels do contribute to higher than background levels of suspended sediment in the West Fork of West Martis Creek.

E. Demonstration of Erosion Control Technology

It must be emphasized that, although a few isolated instances of inadequate erosion control exists at Northstar, the vast majority of the development is an extremely well planned, designed, and constructed example of proper erosion control methods and procedures. In order to demonstrate additional erosion control technology, the remaining problem areas at Northstar were selected for concentrated extra effort. The demonstration of permanent vegetative erosion control and/or drainage control facilities was demonstrated on: (1) steeply cut slopes adjacent to the West Village parking lot and adjacent to the wastewater treatment plant, (2) cut and fill slopes adjacent to Northstar Drive, (3) the unrevegetated and poorly drained ski run near the base of the transport lift, and (4) the heavily travelled dirt road adjacent to the East Fork of West Martis Creek.

Fifty-two different demonstration plots and sections were established on the cuts adjacent to the parking lot, the wastewater treatment plant, Northstar Drive, and the unrevegetated ski run. A variety of different erosion control techniques were demonstrated at those sites, including:

1. Contour willow wattling
2. Willow staking
3. Native shrub plantings
4. Rock lined drainage ditches
5. Rock breast walls
6. Slope scaling
7. Overhang removal
8. Grass seed and fertilizer drilling
9. Grass seed hydromulching rates
10. Grass hydroseeding rates
11. Straw mulching rates
12. Various mulch tackifiers
13. Various fertilizers at differing rates

A complete description of the individual techniques and procedures of those measures listed above is included in Section VIII. Diagrams and tables listing the various plot and section treatments at Northstar are included in Appendix B. Several of the revegetative plantings had to be reconducted at Northstar in order to establish sufficient growth for effective erosion control. Many of the original techniques were unable to establish viable plant growth. The hydromulching techniques, particularly when an additional tackifier was used, did somewhat poorer than straw mulching. The use of willow wattling vastly increased the success of any other revegetation technique used with it. At Northstar, the best revegetative growth for purposes of erosion control was achieved by the following procedure:

1. Removal of all overhangs at the crown of the slope and scale slope surface of loose material.
2. Contour willow wattling placed on slope at 2.0 meter intervals.
3. Hydroseeding slope with at least 100 kg/hr seed mixture.
4. At least 280 kg/ha 16-20-0 fertilizer applied with hydroseeding.
5. Straw mulch blown on slope at a rate of 4500 kg/ha.
6. Straw tackifier used at twice manufacturers recommended application rate.

Please refer to Section VIII for an in-depth description of these and other revegetation methods.

At Northstar, the installation of a wide variety of different temporary sedimentation control devices were demonstrated adjacent to the golf course construction site. In the first half of November 1975, the following were installed:

1. Filter fabric fences
2. Impervious berms
3. Pervious filter fabric berms
4. Pervious sand core berms

These devices were installed so as to provide the waters of West Martis Creek with sufficient protection during the construction of the second 9 holes of the Northstar golf course. All the above listed methods performed well but began to show signs of failure after about 9 months exposure to the elements. In particular, the exposed filter fabric of the filter fences began to degrade because of the exposure to ultraviolet radiation in sunlight. As are the other erosion control methods, the construction of the various temporary siltation control methods is described in detail in Section VIII.

F. Northstar Cost Summary

Northstar is basically a well planned, constructed, and maintained development north of the Lake Tahoe Basin, which has minimized potential adverse environmental impacts. The total cost of the residential, commercial, and condominium development (not including land costs) was about $28,000,000(14). The costs of the additional recreational amenities of the development such as the ski area, the golf course, the recreation center, and equestrian center, were an additional $8,000,000. By assigning the entire cost of the predevelopment planning to environmental impact mitigation and erosion control, the following cost summary may be made:

1.	Predevelopment erosion control	$280,000
2.	Erosion control construction	80,000
	Total	$360,000

Thus, the $360,000 spent for the effective erosion control at Northstar between 1970 and 1973 represents less than 1.3 percent of the total development cost.

As of 1977, there was a total of about 930 developed condominiums and residential lots at Northstar. The total cost of erosion control per currently developed unit is $390. The complete development plan at Northstar calls for a total of over 2,000 developed condominiums and residential lots. The cost per developed unit (in 1973 dollars) is estimated to be reduced to $220 per unit at full development. As shown by this analysis, effective predevelopment planning as conducted at Northstar is an extremely cost-effective method of erosion control.

SECTION VI

RUBICON PROPERTIES: A CLASSIC EXAMPLE OF MASSIVE EROSION PROBLEMS DUE TO POOR PLANNING AND CONSTRUCTION PRACTICES

Rubicon Properties is diametrically opposed to Northstar in terms of the water quality protection and the degree of environmental impact. Northstar's developers went to significant effort to construct a well planned development; Rubicon's developers did little planning. Northstar was constructed with minimum environmental impact; Rubicon Properties was constructed with little environmental awareness. The developers of Northstar exhibit a desire to maintain a minimal environmental impact and to correct remaining minor problems; Rubicon Properties' developers have long since sold all interest in the subdivision and cannot be held accountable for the impact Rubicon Properties is having on water quality and the environment of Lake Tahoe.

Rubicon Properties is a single-family residential subdivision on the west shore of Lake Tahoe, eight kilometers north of Emerald Bay on State Highway 89. There are 632 subdivided parcels in this subdivision of which less than one-half are currently built upon. Approximately one-third of the 128 hectare subdivision is within the Lonely Gulch Creek watershed. The entire Lonely Gulch Creek watershed, as modified by drainage patterns within the development, covers 288 hectares. The watershed ranges from the mouth of Lonely Gulch Creek entering Lake Tahoe at an elevation of 1,898 meters to the top of Rubicon Peak at 2,799 meters. The highest point within the subdivision is 2,127 meters. With the exception of the riparian zone adjacent to Lonely Gulch Creek, the watershed is covered with a relatively dense mixed coniferous forest down to the Lake's shore.

The original land from which Rubicon Properties was subdivided was a 160 hectare parcel held in single ownership. By 1945, several land exchanges and sales had taken place, Rubicon Land Company had been formed, and the lower portions of the original parcel were subdivided. In 1958, 1959, and 1960, the remaining portions of the original parcel, situated higher in the watershed, were also subdivided, resulting in the development we have today.

That portion of Rubicon Properties subdivision specifically chosen for detailed analyses and implementation of erosion control measures was the uppermost 24.4 hectares within the Lonely Gulch Creek watershed to the west of State Highway 89 (See Figure VI-2). The soils of this portion of the subdivision are designated by a recent soil survey (15) as "Meeks" very stoney, loamy, coarse sand, with 30 to 60 percent slopes (MsG). This soil type is representative of the type of granitic soils found in approximately two-thirds of the Lake Tahoe Basin. Erosion hazard is described as being moderate, in undisturbed areas,

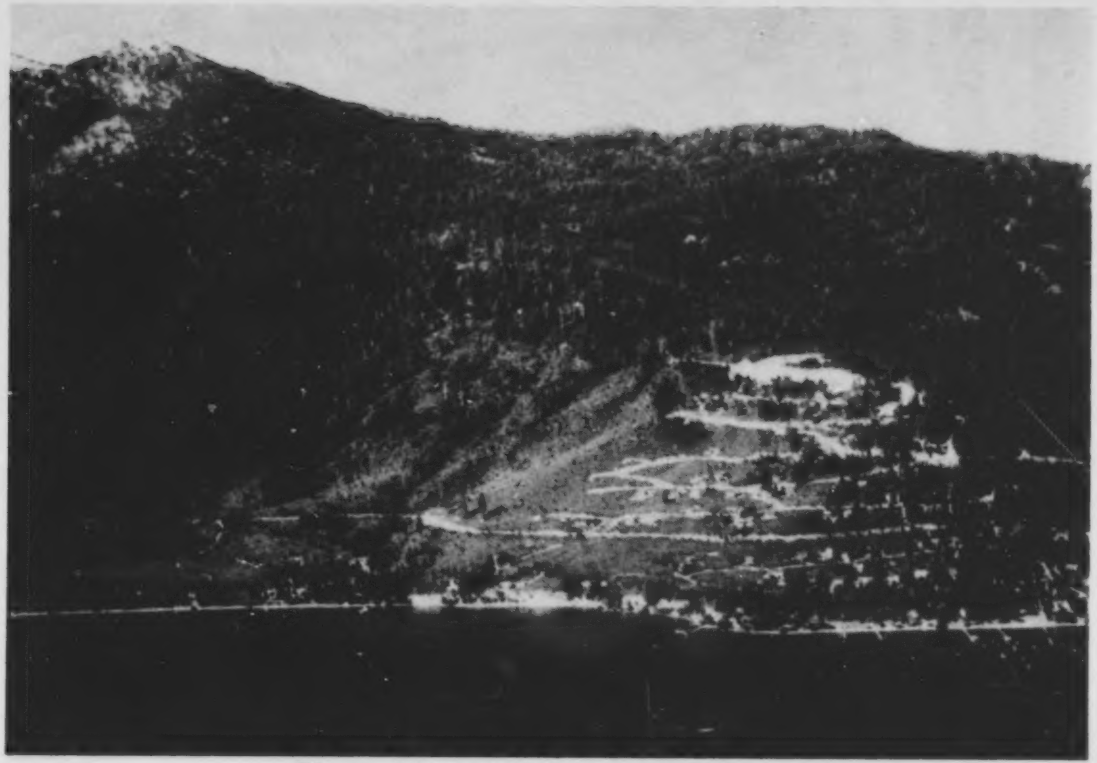


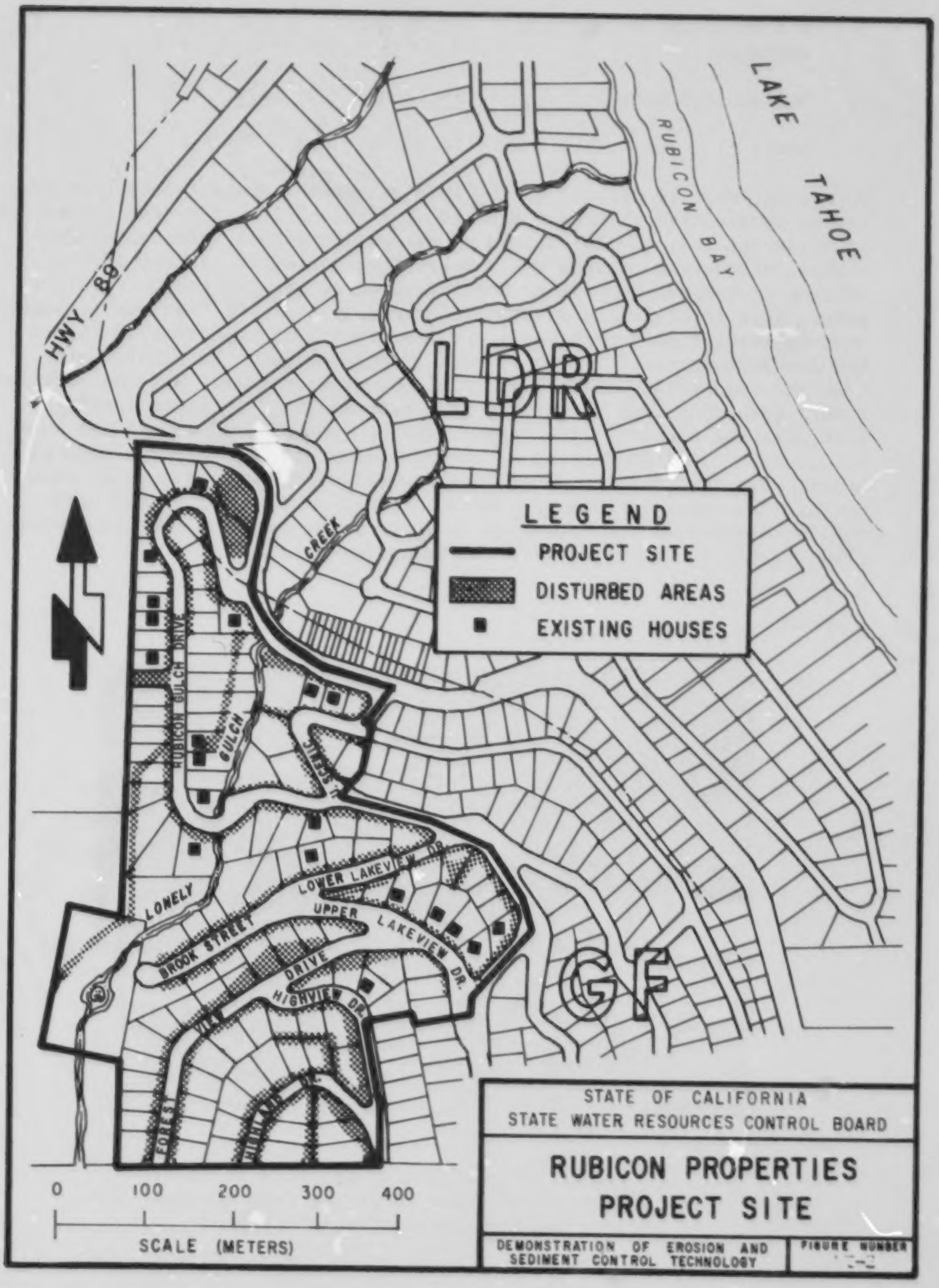
Figure VI-1. Rubicon Properties subdivision on the west shore of Lake Tahoe

to high, in disturbed areas. This is due to a low percolation capacity of the soil, leading to rapid runoff. As a result, the area of the subdivision is classified by the Tahoe Regional Planning Agency (TRPA) in their lowest land capability class (16) which allows only a one percent impervious surface coverage. Furthermore, TRPA has designated "General Forest" as the appropriate land use. However, due to certain "grandfather" clauses in the TRPA charter, residential construction in Rubicon Properties continues to this day.

A. Erosion Problems

When the erosion control project was first started, the land coverage within the area identified for the project site was as follows:

1.	Impervious coverage on private lots	1.15 ha.	5%
2.	Impervious county road surfaces	2.73 ha.	11%


LAKE TAHOE
RUBICON BAY
HWY 89
LDR
CREEK
LEGEND
PROJECT SITE
DISTURBED AREAS
EXISTING HOUSES
RUBICON GULCH DRIVE
GULCH
SCENIC
LONELY
BROOK STREET
LOWER LAKEVIEW DR.
UPPER LAKEVIEW DR.
DRIVE
HIGHVIEW DR.
FOREST
GF
0
100
200
300
400
SCALE (METERS)

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

RUBICON PROPERTIES
PROJECT SITE

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER [illegible]

3.	Disturbed and unvegetated surfaces	3.26 ha.	13%
4.	Undisturbed area	17.22 ha.	71%
	Total	24.36 ha.	100%

Currently, only 19 percent of the lots within the project site have residences constructed on them. With 100 percent build-out in the future, it is estimated that the total area of either impervious surfaces or disturbed, unvegetated slopes would constitute almost 50 percent of that portion of Rubicon Properties designated as an erosion control project site. This is clearly a substantial increase over the "maximum" 1 percent average identified according to the land capability and erosion hazard of the development site. Not only does land disturbance associated with home and road construction lead to higher erosion rates, but concentrated runoff resulting from impervious roof tops and road surfaces further increases the problem. The harm caused by concentrated runoff was unintentionally demonstrated by one homeowner who kept a small flow of water (less than ½ liter per minute) trickling through an outside spigot during the winter of 1976 to prevent pipes from freezing. This very small concentrated flow resulted in a one meter deep and one meter wide eroded swail in his front yard the following spring.

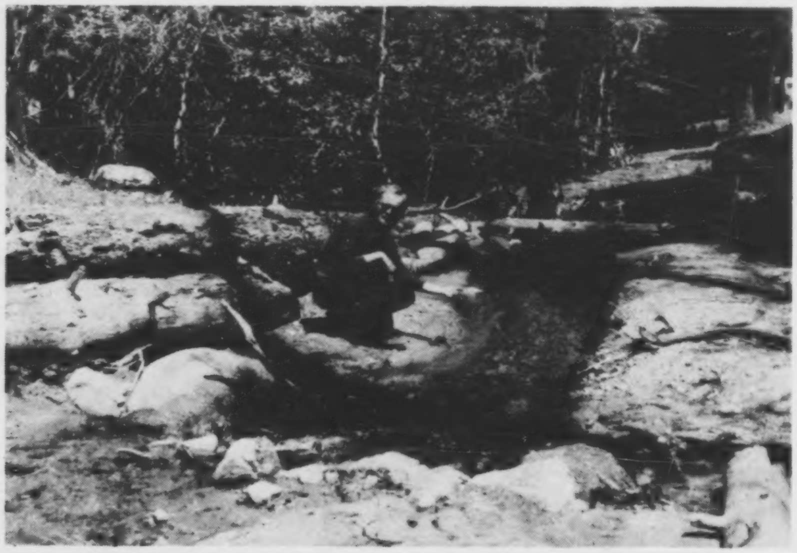


Figure VI-3. Deposition of granitic sediments in Lonely Gulch Creek resulting from erosion within Rubicon Properties subdivision

The majority of the 3.26 hectares of disturbed, unvegetated slopes have not supported any vegetation for the entire 18 years since they were first excavated. Embankments which were originally cut with 1:1 or greater slopes have eroded to 1½:1 slopes or less. Even the exposed granitic layers have probably weathered away at an average rate of 2 to 5 centimeters per year. In most cases, the eroded or weathered material was continually deposited in asphalt concrete drainage troughs at the slope toe adjacent to the paved roadways which zigzag up the hillside. The deposited material remained in these troughs only until the next rainstorm or heavy snowmelt at which time it was rapidly transported down slope through an interconnected system of impervious ditches, culverts, swails, and troughs until it was discharged to Lonely Gulch Creek and, subsequently, to Lake Tahoe.

Longtime residents of the area have indicated that fishing Lonely Gulch Creek was a common occurance prior to construction of the development; (the creek apparently sustained a healthy trout population). Prior to the early 1930's, development consisted of 1 residential estate which tapped Lonely Gulch Creek for hydroelectric power generation and incidental domestic water supply. Since the upper portions of the development were added in the late 1950's, it is extremely unlikely that any trout could survive in that portion of the stream affected by runoff from the subdivision. Indeed, as discussed in Section VII, benthic macroinvertibrate populations monitored between 1972 and 1976 have shown up to a 99 percent reduction in aquatic life in affected downstream portions.

Clearly, the upper portion of Rubicon Properties subdivision has been the site of massive erosion since it was constructed in 1959. Through discussions with local residents, the State Board staff has been able to estimate the original configuration of the unstable cut and fill slopes. By comparing their estimates of prior conditions with current slope configuration, the amount of material eroded from the erosion project site since 1959 was estimated to be 6,255 cubic meters or 8,660 metric tons. Thus, an average of 1,975 metric tons per square kilometer per year are estimated to have eroded from the project site between 1959 and 1976. As discussed in Section VII, the current sediment discharge from the project site was estimated to be 366 metric tons per square kilometer per year for 1975 to 76. Based upon this analysis, it must be assumed that considerably more sediment was eroded from the upper portions of Rubicon Properties immediately after construction than is currently being eroded. This is quite reasonable in view of the fact that over a period of 18 years the original slopes within the development had been eroded to less severe slope angles, more nearly approaching the angle of repose of the soil. This action has led to the gradual "natural" stabilization of some slopes during the period from 1959 to 1976. Assuming a straight line curve between 1959 and 1976, Table VI-1 depicts the estimated erosion rate for each year of this period.

Although predevelopment water quality and hydrologic monitoring was nonexistent, water quality of the undisturbed 235 hectares of Lonely Gulch watershed above Rubicon Properties is assumed to be representative of predevelopment conditions for the entire watershed. The upper portions of the watershed have not been significantly disturbed, since logging operations were last conducted over 100 years ago. Based upon the water quality monitoring program described in Section VII, the natural background level of erosion for the upper, undisturbed portions of Lonely Gulch Creek watershed is 3.43 metric tons per square kilometer per year. The geologic configuration and soil type found in the upper portions of the subdivisions are slightly different from the upper watershed. Nonetheless, it has been assumed that the natural background rate of 3.43 metric tons per square kilometer per year is a reasonable assumption for all undisturbed portions of the watershed. Thus, the monitored average erosion rate of 366 metric tons per square kilometer per year for the period of 1973 to 76 is a 10,600 percent increase above assumed natural background levels. Even more astounding is the possibility that the initial erosion rate after the construction of Rubicon Properties, as depicted in Table VI-1, may have been as high as 3,669 metric tons per square kilometer per year - over a 100,000 percent increase above assumed natural background levels.

From the standpoint of erosion control, the upper portion of the Rubicon Properties subdivision is clearly representative of a poorly planned, designed, and constructed development. Had the county with jurisdiction properly exercised the constraints which were embodied in their own subdivision ordinance in 1959, the upper portions of Rubicon Properties might never have been constructed. The county subdivision ordinance in effect in 1959 required that the county road right-of-way must include all road cuts and fills associated with road construction (17). Currently about 90 percent of the disturbed slopes within Rubicon Properties lie outside the county maintained road right-of-way. Had the ordinance been enforced, there would have been over 14 percent less developable land available for subdivided residential lots. This may very well have discouraged the developer from the standpoint of anticipated revenue. Even if the development had still been constructed, adherence to the subdivision ordinance would have left the majority of the most severe erosion problems under single ownership, which would have greatly facilitated problem correction.

The poor planning and construction of the upper portions of Rubicon Properties goes beyond generating excessive erosion and sedimentation problems. Improper or inadequate roadway construction, domestic water supplies, storm water drainage facilities, sewage treatment facilities, and lowered aesthetic appeal are also embodied in Rubicon Properties subdivision.

B. Roadway Construction Problems

The roadways within the upper subdivision pose a maintenance problem for the county, and will continue to be a problem even with erosion and sediment under control. Several roads have grades in excess of 15 percent. Once again, the county subdivision ordinance, which allowed a maximum grade of 12.5 percent in 1959 (17), was ignored by the developer and not enforced by the county. Even 12.5 percent is very steep as compared to

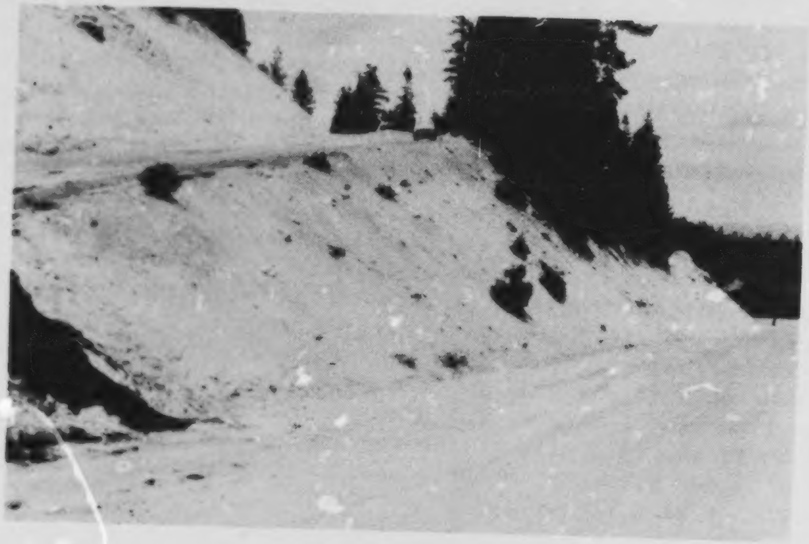


Figure VI-4. Steep roadways and oversteepened cut and fill slopes within Rubicon Properties subdivision, Lake Tahoe Basin

TABLE VI-1
ESTIMATED YEARLY EROSION RATES
FROM THE UPPER 24.4 HECTARES
OF RUBICON PROPERTIES FROM
1959 THROUGH 1976

Year	Erosion Rate (Metric Tons/ha/yr)	Year	Erosion Rate (Metric Tons/ha/yr)	
1959	36.20	1968	17.30	
1960	34.10	1969	15.20	
1961	32.00	1970	13.10	
1962	29.90	1971	11.00	
1963	27.80	1972	8.90	
1964	25.70	1973	3.66	
1965	23.60	1974	3.66	4-Year
1966	21.50	1975	3.66	Average
1967	19.40	1976	3.66	

Natural background erosion rate monitored from undisturbed watershed = .0343 metric tons per hectare per year (1973, 1975-76) current standards. The maximum road grade currently considered practical for access in mountainous regions is 6 percent. The primary reason for this is the difficulty of removing snow on steeper roadways. In addition, ice formation on steeper grade makes access extremely difficult for standard automobiles and poses a severe traffic hazard. As the upper portions become developed further, it is anticipated that the level of winter road traffic will continue to increase, further increasing the road hazard.

Snow removal equipment has an extremely difficult time within the upper portions of Rubicon Properties, particularly in very severe winters. The large vehicles have problems negotiating the extreme switchback turns which exist in the subdivision and frequently cannot gain traction on the steep road surfaces. Furthermore, the close proximity of the steep road cuts to the road surface severely limits the amount of snow storage area. As a result, the snow removal equipment invariably operates too close to the fill side of the roadway, rupturing curbs, dikes, and gutters. These breaches in the roadside structures cause further overland discharge and erosion problems.

C. Storm Water Drainage Problems

Because of the extremely steep terrain and high percentage of disturbed land and impervious surfaces (29 percent), adequate drainage control in the upper portions of Rubicon Properties is extremely difficult. Drainage ditches, curbs, and gutters, culverts, and sectional downdrains used within the development are generally undersized for the extreme flows which occur during high runoff events. The adequacy of these facilities is further decreased by constant clogging with eroded soil from the disturbed terrain. Prior to the erosion control project, substantial areas within the development did not even have dikes to prevent road surface runoff from flowing over adjacent fill slopes. One slope, a 0.4 hectare fill area, lost at least 1.0 meter of soil, averaged over the entire slope face, due to the absence of dikes. The drainage ditches used to convey snowmelt or storm runoff are all unstable, unlined eroded swails. In many instances, flow from corrugated metal pipe culverts was allowed to spill over unstable steep soil surfaces prior to discharge to the Lonely Gulch Creek. The result has been the appearance of several deeply eroded artificial swails.

While the current level of development has created substantial areas of disturbed or impervious surfaces, it is nothing like the level which would be reached upon full development of the subdivision. The existing drainage facilities are inadequate for the current level of development (16 percent impervious surfaces). With full development (37 percent impervious surfaces), drainage problems will be considerably magnified. Without substantial revamping of the drainage facilities and complete erosion control, Rubicon Properties will not be able to bear the load of full development without major failures of the existing drainage system.

D. Maintenance Procedure Problems

Numerous improper or questionable maintenance practices have been observed to be conducted within Rubicon Properties subdivision by the various local maintenance and utility agencies. These practices generally increase the rate and/or the amount of erosion which would otherwise occur within the subdivision. The most visible of improper maintenance practices is the application of sand to road surfaces in the winter time without adequate provisions for cleanup and removal of applied sand. Depending on the severity of the winter, anywhere from 10 to 40 metric tons of road sand are applied to 2.5 kilometers of roadways within the Rubicon Properties project site annually. This applied road sand may account for 5 to 25 percent of the suspended sediment load which has been monitored in Lonely Gulch Creek. In most years, only token attempt is made to cleanup and remove applied road sand. This is generally performed by a mechanized roller broom. This technique removes the road sand from the street surface (only to be redeposited in roadside ditches or downslope areas) and does little to reduce the amount of road sand which is eventually washed into Lonely Gulch Creek and Lake Tahoe. A more appropriate procedure would employ vacuum type brooms for the removal and proper disposal or reuse of the waste road sand. In addition sediment catchment basins or drop inlet structures should be provided to collect any remaining waste road sand which could be washed from the road surface.

Other maintenance practices also increase the rate and/or amount of sediment yield from the Rubicon Properties project site, or otherwise increase the severity of the development's erosion problems. Among them are:

1. The practice of removing accumulated sediments from the toe of an eroding slope which undercuts the stability of the slope and leads to an increased erosion rate. Better practice would be to move existing drainage further away from the toe of an eroding slope, or construct a retaining structure.

2. Washing culverts and drains clogged by eroded sediments increases the rate of downslope sediment transport. Better practice would include the dry boring or reaming of the culverts to remove sediments coupled with the proper disposal of the waste earthen materials.

3. Insufficient snow stakes can result in increased damage to curbs, dikes, gutters, retaining structures, and slope toe benches by snow removal equipment.

4. Improper disposal of waste earthen material, such as "over-the-bank" practices, increases sediment transport and hinders the proper establishment of slope stabilization measures. Better practice would include the disposal of the waste earthen material to a land fill or the washing and reuse of the material as winter road sand.

5. Negligence in providing revegetation or other stabilization to areas disturbed for the connection of sewer and water laterals or other underground utilities. Frequently, the disturbed surface acts as a channel for upslope storm runoff or snowmelt runoff. Better practice would include immediate restabilization using vegetation, mulch, nets, blankets, waterbars, check dams, or other devices.

In most instances it appears that these improper practices are conducted as a result of ignorance on the part of the maintenance workers, the lack of proper equipment to perform the task, and the intransigence of management to provide the proper incentives.

E. Other Problems

In addition to development problems which increase erosion rates, there are also a number of other problems within Rubicon Properties subdivision. These additional problems also substantiate the considerable lack of planning and environmental awareness which preceded construction of this development.

1. Domestic Water Supply

The sole source of domestic water supply is a small storage and diversion facility on Lonely Gulch Creek. The original diversion, initiated in the early 1920's, was for hydroelectric power generation and the incidental domestic use of one estate. Since that time, the manner, location, and duration of the water use of water diverted from Lonely Gulch Creek has changed—all in probable violation of California water rights law. Currently diverted water is used to supply approximately 300 households solely for domestic supply, some of which are not even located on the original parcel. Furthermore, the original seasonal use (May-September) has been extended to year round use.

The foregoing, however, is not as severe as the fact that there simply is not sufficient streamflow in Lonely Gulch Creek to provide a safe supply for the subdivision. Although the subdivision is less than 50 percent built-out, streamflow is frequently reduced to zero as a result of the diversions for domestic supply. In 1976, a very dry year, there were 25 twenty-four hour periods when streamflow was zero. Even in 1973, an average water year, there were periods of several days when streamflow was zero. Had the most recent upper portions of the subdivision not been added on in the late 1950's, there would be sufficient streamflow in the creek to provide for the complete build-out of the original subdivided parcels. However, even if this were the case, streamflow in Lonely Gulch Creek would frequently be reduced to zero. This would still have caused significant damage to the aquatic life and riparian vegetation of Lonely Gulch Creek.

At the present, development of additional sources of water supply are somewhat dubious due to current uncertainty of water rights and water availability within the Tahoe Basin as a whole (18, 19). Clearly, the developers of Rubicon Properties subdivision, and the local agencies, and the utilities did not consider the long-term water supply problem which would be encountered upon complete build-out of the development.

2. Sewage Treatment

Prior to 1973, domestic sewage waste within Rubicon Properties was treated individually by septic tank and leachfield systems. However, very few homes were existing in the upper portions of the development where the thinnest soils are found. For this reason, potential health problems did not appear. At full build-out, the upper portions of Rubicon Properties subdivision would have been unable to support septic tanks and leachfield systems sufficient to serve over 100 single family residences located on less than 25 hectares of land. The possibility of health problems would have been increased further by the large cuts and fills adjacent to the roadways. Domestic sewage disposed in leachfields would certainly have resurfaced at several locations within the subdivision. Springtime snowmelt seepage areas and very small perenial springs are manifest throughout the area, particularly on road cuts. The installation of a regional sewage collection system in 1973 ended the threat to public health resulting from further expansion and use of septic tanks and leachfields. However, the undergrounding of the collection system substantially increased the sediment yield and erosion rate during construction. This occurrence, again, emphasized the extreme fragility of the area and the adverse impacts imposed by conventional construction practices.

Potential sewage treatment problems have not been eliminated with the addition of a sewage collection system. Providing adequate sewage treatment and disposal facilities is a problem currently facing not only Rubicon Properties but most of the Lake Tahoe Basin. Rubicon Properties subdivision receives sewer service from the Tahoe City Public Utility District (TCPUD). The TCPUD is a member of Tahoe-Truckee Sanitation Agency (TTSA), the regional entity designated to treat and dispose of wastewater from the north and west shores of Lake Tahoe and the Truckee River area downstream to Truckee. Wastewater treatment and disposal facilities are presently under construction by this agency.

In a June 19, 1975, action, the State Water Resources Control Board set maximum seven-day average flow limitations for all districts, including TCPUD, that are served by TTSA. This will effectively limit the number of additional sewer connections allowed in individual districts, which in turn will limit the number of existing unimproved subdivided lots which can be built upon. An estimate of remaining available connections for TCPUD and North Tahoe Public Utility District (NTPUD) is set at 1,258 single family dwelling unit equivalents. In the TCPUD and NTPUD combined, there exist 6,200 undeveloped lots.

A treatment plant expansion could occur; however, no design, financing, or environmental documents have been prepared for such a project. As with other aspects of Rubicon Properties subdivision, the developers, local regulating agencies, and utilities gave little considerations to the sewage treatment problems which would surely occur with the development of the upper portions of the subdivision.

3. Aesthetics

One visit to Rubicon Properties gives a clear indication as to why it was developed in the first place. The location of the subdivision affords the resident and visitor a spectacular view of the Lake Tahoe Basin. No doubt this fact was on the developers' mind when judging the marketability of the development even before the first bulldozer swath was cut. Because of its location on steep terrain, a "staircase" effect is created by the road switchbacks. Each successive level of residential lots allows a clear view of the Tahoe Basin over the roof of the downslope neighbor.

While the location of Rubicon Properties offers a spectacular view from the development, the series of switchback scars are readily visible from many parts of the Tahoe Basin; a highly visible testimony to man's impact on the Lake Tahoe Basin.

F. Demonstration of Erosion Control Technology

The upper portion of Rubicon Properties subdivision is a unique and classic example of all around poor planning and construction practices. Seldom is it possible to find such extensive erosion, drainage, water supply, sewage treatment, road maintenance, and aesthetic problems all concentrated in a single subdivision. However, from the standpoint of demonstrating erosion control technology, it is a concentrated representative sample of the most severe types of erosion problems. These problems are found throughout the Lake Tahoe Basin and other rapidly developing mountainous regions of California. Large cut and fill slopes, steep cut and fill slopes, small cut and fill slopes, abandoned dirt roads, heavily traveled dirt roads, clear cut vacant lots, and various examples of concentrated drainage problems are all found within the upper portion of Rubicon Properties subdivision.

Rubicon Properties also offers an excellent site for demonstration of erosion and sediment control technology because the impact of uncontrolled erosion and sedimentation has been well documented within Lonely Gulch Creek. Section VII describes in detail the monitoring program which was conducted in the Lonely Gulch Creek watershed to document the water quality impact of development there. Because of the successive switchback layers of the subdivision, the impact of the most severe erosion problems found within the subdivision are concentrated within the Lonely Gulch Creek watershed.

In June 1975, the staff of the State Board in agreement with the staff of the Regional Board, selected portions of Rubicon Properties as a project site to supplement the effort already being conducted at Northstar. The project site was identified as the area shown in Figure VI-2. By working from the highest to the lowest points within the project site, within the time (July 1974 through July 1977) and funding constraints of the program, it was felt that the most severely eroded sediment discharges to Lonely Gulch Creek could be progressively corrected.

The first major obstacle which was encountered involved obtaining permission to gain access to eroding property from every effected landowner within the project site. A high level of response and support was gained from the respective landowners, but much staff time, including legal staff support, was required to gain the required permission. By the time the necessary license agreements were fully executed in the fall of 1975, very little time remained for construction of erosion control facilities prior to winter snowfall. When erosion control problems within a development are the responsibility of a single owner similar to the Northstar development, the logistics of effective erosion control are greatly facilitated.

During the summer and fall of 1976 and spring of 1977, a wide variety of erosion control techniques were demonstrated at Rubicon Properties. Ninety percent of all disturbed areas, including the most severe, were treated. Demonstrated erosion control techniques included the following:

1. Rock and gabion breast wall
2. Gabion retaining walls
3. Relocation of curbs, dikes and gutters
4. Overhang removal
5. Slope scaling
6. Contour willow wattling
7. Willow staking
8. Various seed mixtures
9. A variety of hydromulching application rates
10. Straw mulching
11. A variety of straw mulch tackifiers
12. A variety of mulch nets and blankets
13. Rock lined channels

Complete detailed description of these and other erosion control techniques are included in Section VIII. Appendix B describes the location of the various methods demonstrated within Rubicon Properties. A total of 117 herbaceous seeding "plots" and 20 "sections" containing shrub and tree plantings are located within the Rubicon Properties project site. The total land area treated amounts to approximately 2.9 hectares of eroding cuts, fills, slopes and other eroding, unvegetated problem sites.

Little was done to correct the extreme drainage problems which accompany and exacerbate the erosion and sedimentation problems. Drainage control within Rubicon Properties would be an extremely expensive proposition and would have required about 50 percent more funds than were available. Project funds were used to correct drainage problems most directly related to, or causing, erosion problems. Construction of curbs, dikes, gutters, and retaining walls, for example, enhance drainage control while at the same time correcting erosion problems. The cost of drainage structures should not be assigned solely to erosion control; part should also be assigned to drainage and flood control.

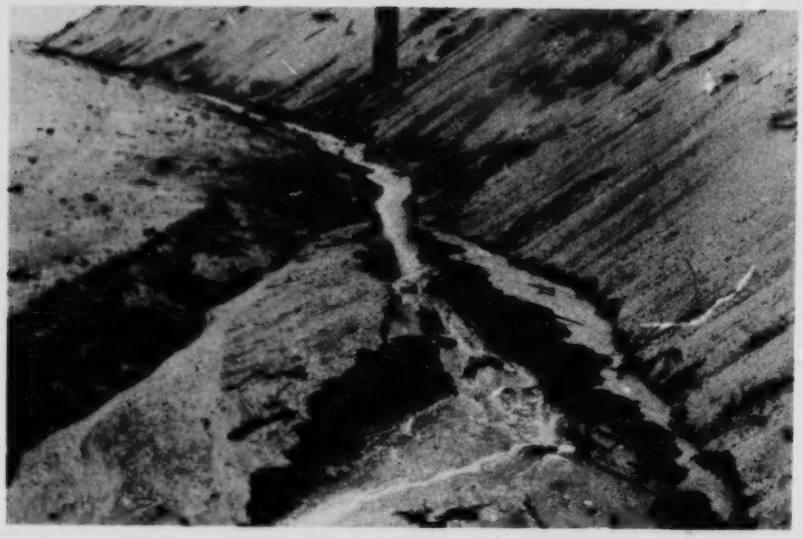


Figure VI-5. Eroded and accumulated sediments at toe of oversteepened cut slope within Rubicon Properties subdivision, Lake Tahoe Basin, during the summer of 1975

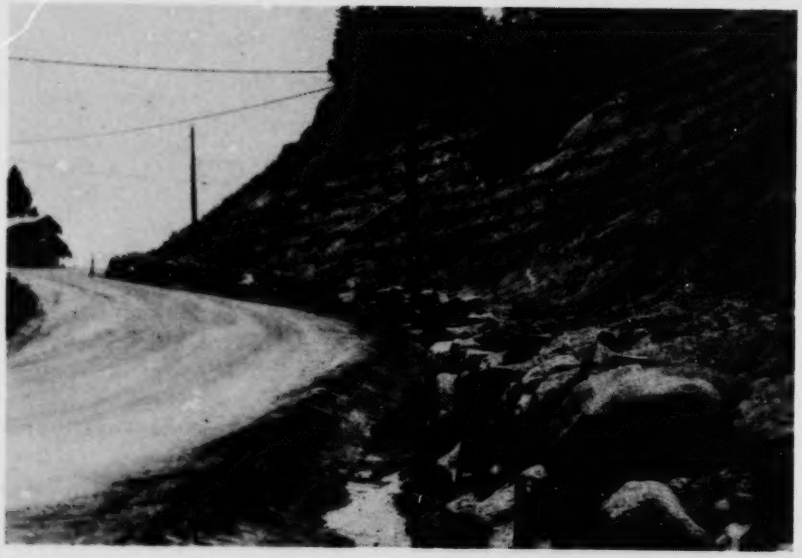


Figure VI-6. Oversteepened cut slope after application of mechanical and revegetative erosion control techniques with an estimated 80-90% effectiveness in reducing erosion rates. Picture taken in the summer of 1977

G. Cost Effectiveness

A qualitative evaluation of the erosion project at Rubicon Properties has been made. According to county personnel, 1977 is the first year in memory when massive cleanup efforts were not required following snowmelt and rainstorms. Admittedly, 1977 has been a very dry year with little snow. However, near normal precipitation conditions were recorded in May 1977. No substantial cleanup operations were required during this month. Prior to installation of erosion control measures at Rubicon Properties, the county would typically spend approximately $11,500 per year for county personnel and equipment (230 hours of a two-person crew per year plus equipment) to unclog culverts and cleanup erosion problems within the project site. The total cost to the county of El Dorado and the State of California to install the extensive erosion control measures within the project site are listed in Table VI-2. The actual total unit cost of the erosion control project at Rubicon Properties, including the assumed value of other contribution of labor, equipment, and material, is estimated to be $41,621 per hectare. The unit cost to perform an equivalent project on a commercial basis, based on individual unit cost estimates provided in Section VIII would be over $76,000 per hectare. Thus, if the following assumptions are valid:

1. Negligible erosion and sediment control maintenance would be required after a project similar to the one conducted at Rubicon Properties.
2. The long-term increased maintenance cost rate is 6 percent (based upon the 27 year Engineering News Record construction cost index average since 1950).
3. Money may be borrowed by the county at 8 percent interest.

Then, the cost of erosion control, such as that conducted at Rubicon Properties, would be amortized over a 12.5 year period. This analysis also assumes all erosion control construction costs are charged against the county maintenance budget only. This means that none of the erosion control costs are assigned to environmental protection, enhancement, or to other entities besides the county. Thus, erosion control is clearly feasible, particularly if support is provided from sources other than from just the directly benefiting and/or directly responsible entity.

H. Recommended Control Measures

Based upon an early assessment of the effectiveness of the methods employed at Rubicon Properties, it is possible to make preliminary conclusions regarding effectiveness and cost of specific erosion control techniques. For a more detailed discussion of erosion control methods and their effectiveness refer to Section VIII.

General recommendations on individual erosion control methods are extremely difficult to make. Application of each method is highly site specific. Different erosion control methods may be best applied, either singly or in combination, to different sites depending on conditions.

There is no one "best" method to control all erosion problems. At a minimum, the following are the major criteria which must be evaluated prior to selection of particular erosion control methods:

1. Soil (or subsoil) type, particle size and nutrient content
2. Slope length
3. Slope angle
4. Drainage patterns
5. Climatic conditions
6. Soil moisture
7. Exposure and aspect
8. Surrounding vegetation types
9. Underlying geology and location of seepage areas

If any one of the above criteria changes from one site to the next, recommended erosion control methods for a specific site may require substantial alteration. All erosion control techniques demonstrated at the Rubion Properties project site achieved some degree of initial success. It is too early to determine a significant difference between techniques or combinations of techniques, particularly as to their long-term effectiveness. The best yard stick available to measure success at this early date is simply the treatment cost.

The establishment of vegetation using seed and small amounts of fertilizer, followed by a straw mulching and tacking process is generally the least costly method. However, on steep, rocky terrain, even several seeding and straw mulching-tacking operations may not be successful. In such cases, the use of mulch nets and blankets, although frequently five times as expensive, may be the only technique which can successfully revegetate such a severe site. Similarly, the use of willow wattling, though extremely expensive, vastly increases the chances of establishing vegetation on difficult sites. The following control methods appear to be the best techniques for successfully controlling erosion problems such as those found within Rubicon Properties. At other locations however, other methods may achieve a higher degree of success depending on the prevailing site conditions. Section VIII of this report offers a more detailed discussion of all erosion control construction techniques demonstrated at Rubicon Properties.

1. Slope Preparation

   Slope preparation is frequently the most important step in controlling erosion. This includes the diversion of drainage waters away from unstable slope areas, removal of loose rock and debris, and the removal of overhangs from the top of an eroding slope. The top portion of an eroding slope should never be steeper than the lower portions. If possible, the entire slope should be laid back to the angle of internal friction (angle of repose) of the soils found at the site. If this is not possible the use of extensive mechanical stablization, such as revetments or willow wattling, will be required.

TABLE VI-2

EROSION CONTROL COSTS AT RUBICON PROPERTIES PROJECT SITE

DIRECT EXPENSES		
County Road Crews and Equipment		$51,000
Special Equipment Rental		17,000
Gabions and Rock Fill		23,000
Unskilled Youth Labor		23,000
20,000 Rooted Plants		15,000
Miscellaneous Materials & Equipment		5,000
	Subtotal	$113,000
CONTRIBUTIONS OF OTHERS		
(Equipment) Soil Conservation Service		2,000
(Labor) Forest Service & Homeowners		3,000
	Subtotal	$ 7,000
	TOTAL	$120,000

Total Land Area Treated = 2.90 Hectares
Average Unit Cost = $41,621 per Hectare
Estimated Equivalent Commercial Cost = $76,849 per Hectare

2. Contour Willow Wattling

Contour willow wattling is an extremely effective method of controlling erosion on excessively steep and lengthy slopes (both cut and fill). However, care must be taken in the installation of this method. The best time for installation is in the early spring or late fall. Summer planting is discouraged because of the high transpiration losses suffered by a fully leafed willow branch prior to the growth of a new root system. Without willow wattling, the establishment of vegetation on sandy-type soils with slope angles greater than 2:1 is next to impossible. Even if contour willow wattling does not root and grow, it provides flexible mechanical stabilization which then enables other vegetation to take root and grow.

3. Straw Mulching

Almost all planting techniques demonstrated at Rubicon Properties have high degrees of initial plant growth and survival. However, drought tolerant herbaceous seeding, followed by straw mulching and tackifying appears to be the most cost-effective all around treatment for many sites. Generally, a complete straw mulching treatment may be applied on a commercial basis at rates ranging from $3,000 to $3,500 per hectare. This makes it one of the most inexpensive techniques demonstrated. A "tacked straw" treatment provides a flexible, strong, light reflective, moisture retentive matrix, and ample protection for seed germination and plant growth. Superior stands of grass and shrub seedlings have been observed on most plots which received a straw mulch treatment. However, in the case of a straw mulching treatment, as with all other seeding techniques, provisions should be made for reapplication of seed, fertilizer, straw, and tackifier if the first application is not successful due to adverse climatic conditions.

4. Slope Toe Foundations

Adequate slope toe foundations are essential to provide stability to an eroding slope. At Rubicon Properties, 0.9 meter to 2.7 meters high retaining walls were used to provide adequate slope toe protection. These were generally used where existing paved street surfaces were equal to, or less than, their minimum allowed width. El Dorado County ordinances require that paved road surfaces must be maintained at a certain percentage of the available right-of-way. Within Rubicon Properties, the required paved road width was generally 7.9 meters. In areas where sufficient paved road surface was present, existing curbs, dikes, and gutters were removed and replaced further into the right-of-way at a greater distance from the slope toe. This eliminated the need to construct large walls to provide adequate slope-toe protection. Reconstruction of the curb, dike and gutter system could be performed at costs ranging from 10 to 25 percent of the cost of breast walls or retaining walls. Had a minimum paved road surface not been required at Rubicon Properties, relocation of existing curbs, dikes, and gutters could have been universally applied as the means of providing adequate slope-toe stabilization. This would have reduced the unit cost of erosion control within Rubicon Properties from over $41,000 per hectare to less than $26,000 per hectare. This represents a cost savings of over 35 percent.

SECTION VII

THE IMPACT OF DEVELOPMENT ON WATER QUALITY

A. INTRODUCTION

As part of the Erosion Control Demonstration Project the State Water Resources Control Board (State Board) has conducted an extensive monitoring program at the two project sites. The emphasis of the program has been placed upon determining to what degree suspended sediment is generated by the Northstar and Rubicon Properties developments. In addition, the degree to which the respective streams are affected by erosion has been thoroughly documented by this study. Water quality monitoring programs have been conducted at both Northstar and Rubicon Properties. The following parameters were monitored as part of this Erosion Control Demonstration Project:

- Streamflow
- Suspended sediment concentration
- Precipitation
- Benthic macroinvertebrates
- Snow depth and snowmelt (Northstar only).

The purposes of the monitoring program were threefold: (1) to determine the location and extent of any high sediment yield from within the respective developments, (2) to establish, if possible, a measurement of the total sediment mass emission from each development and from various portions of each development, (3) to make a comparison, if possible, of post-development sediment yield with estimated predevelopment conditions. A digital computer and a water quality modeling program were used to handle the extensive amount of streamflow and suspended sediment data. The program also allowed the State Board staff to estimate the total suspended sediment mass emission for both predevelopment and postdevelopment conditions at Northstar and Rubicon Properties. The formulation and operation of the water quality model is described in a subsequent part of this section.

B. WATER QUALITY MONITORING PROGRAM

The following methods and procedures were used to monitor and collect data pertaining to erosion and sediment yield from the Northstar and Rubicon Properties developments.

Streamflow

Stevens Type F water stage recorders positioned in stilling basins directly upstream from sharp-crested weirs were used to provide continuous streamflow data. The recorders were manually reset on a weekly basis. Continuous streamflow recordings were then digitized in terms of stage height versus time using a Bendix Data Grid Digitizer and stored on magnetic computer tape.

Suspended Sediment Samples

Suspended sediment field and laboratory procedures were those established by Burgy and Knight for use by the State Board for the assessment of silt and sediment pollution problems(20). Samples were collected using an integrated suspended sediment hand sampler designed by Robert H. Burgy. Samples were collected upstream and downstream of areas of man-made land disturbance where possible. Direct discharges of suspended sediment into streams were also collected by grab sampling.

Suspended sediment was analyzed using the Total Suspended Matter (Non-filterable Residue) method as described by the U.S.G.S.(21). The water sample is filtered through a predried, tared 2.1 centimeter glass fiber filter (Reeve Angel, Grade 934AH) in a Gooch crucible. The filter and the crucible are then dried at 103 degrees centigrade and cooled in a desiccator to room temperature. The samples are then weighed and the results are reported as parts per million suspended sediment.

Benthic Macroinvertebrates

Benthic macroinvertebrate communities, mostly aquatic insects which inhabit the stream bottom in their immature stages, were sampled in several areas near Northstar and Rubicon Properties, above and below zones of land disturbance. Similar investigations in other areas have shown that the structure and population of macrobenthic communities were adversely affected below areas where sediment has been discharged into streams. This relationship suggests that benthic macroinvertebrate data may be used to indicate that excessive sedimentation has occurred in suspected areas. In addition, it offers an assessment of the direct impact that silt has on aquatic biota.

Surber sampling of a one square foot section of stream bottom for each sample was the method of collection employed for benthic macroinvertebrates(22). Due to the rocky substrate of the stream bed and the shallow depth of the streams, it was decided that Surber sampling would be the most efficient and effective collection technique. Using the Surber square foot sampler, Needam and Usinger(23) determined that the 194 samples were required for an estimation of total wet weight, and 73 samples were needed for an estimation of total numbers of bottom organisms to attain significant figures at the 95 percent level of confidence. However, only two or three samples were needed, at the

95 percent level of confidence, to insure that at least one member of each of the commonest genera of bottom organisms would be present.

Allen(24) and Davis(25) discovered that when samples are taken at places selected by the eye to be as environmentally similar as possible, there is a smaller range of variation between samples. In gridded or randomized series sampling, the coefficient of variation in Allen's sampling was between 0.4 and 0.5. In sampling uniform areas, the coefficient of variation was about 0.2.

In this study, an attempt was made to sample riffle areas of the same depth, velocity, and substrate type. Stations, where three to four samples were taken, were located above and below areas of man-made land disturbance and sediment discharges according to the recommended methods of Cairns and Dickson(26). Where possible samples were taken well above a sediment discharge, immediately downstream of the discharge, and at various locations well downstream of the discharge to determine the linear extent of damage. For some streams at Northstar, it was impossible to obtain samples above the discharge from clear-cut ski runs.

Macroinvertebrates collected from each square foot of substrate were placed in Mason jars with a preservative of 50 percent alcohol (95 percent), 5 percent glacial acetic acid, 10 percent formalin, 3 percent glycerine, and 32 percent distilled water by volume. The samples were then dyed red with a rose bengal solution to facilitate hand picking of the benthos from the bottom substrate and ditritus. The macroinvertebrates were sorted and identified to the lowest practical taxonomic level, (27,28,29) counted and weighed (i.e., dry weight at 103 degrees centigrade for one hour).

Species diversity indices were calculated using numbers and weights for each station. The diversity index chosen was the Shannon-Weaver formula(30) based on information theory. The diversity index was calculated as:

$$\overline{d} = -\Sigma N_i/N\ (\ln N_i/N)$$

where "N" is the total number of individuals and "N_i" is the total number of individuals in each genus.

In addition, the diversity index was partitioned into two subcomponents: (a) species abundance or richness as represented by the number of species, "S", and (b) evenness as represented by $e=\overline{d}/\log_2 S$, where "e" is an index of distribution of individual organisms among species(31).

The approximate *t*-test(32) was used to determine statistically significant differences between stations in regards to total numbers per square meter (density). This test is recommended for sample means whose variances are heterogeneous. In contrast, a t-test defined by

Hutcheson(33), as recommended by Burgy and Knight(20), was used for comparing diversity indices. The latter t-test employs the variances of the diversity indices calculated from each station in computing t and in computing the degrees of freedom. Since, in all cases, the upstream stations are considered to contain the natural benthic community of each stream, the downstream stations were examined to determine whether deviations from the normal community existed.

Percent similarity was also determined between stations to identify differences in community types. Percent similarity is defined as:

$$PS = 100-0.5 \sum_{i=I}^{S} (a_i - b_i)$$

where "S" is the total number of species present, "a_i" is the percent of individuals in species "i" in community "A", and "b_i" is the percent of individuals in species "i" in community "B"(34).

Precipitation

Battery operated, heated (either electric or propane), recording rain-snow precipitation gages were used to monitor precipitation amounts and intensities. The recorders were reset on a weekly basis.

Snow Depth and Water Content (Northstar only)

Snow course stations were established and samples were taken according to procedures established by the U. S. Soil Conservation Service(35) and used by the California Department of Water Resources. Samples were taken by steel snow sampling tubes and weighed on a scale calibrated in inches of water. Five samples per snow course were taken on a bimonthly to monthly basis. Snow depth, water content, and snow density data, and a qualitative description of apparent soil moisture were recorded for each snow course.

C. WATER QUALITY OF WEST MARTIS CREEK (NORTHSTAR)

The 10,500 hectare watershed of Martis Valley Creek is located immediately north of Lake Tahoe; however, West Martis Creek, the area of investigation, contains only 1300 hectares. Mean annual precipitation ranges from 60 to 100 centimeters from the lower elevations to the top of Mount Pluto falling mostly as snow. The stream flows down a moderately steep course until it reaches Martis Creek in the valley floor.

Soils of the watershed are principally weathered andesite derived from a central ridge of volcanic material which divides Martis Valley Creek watershed from Lake Tahoe. Higher elevations are characterized by shallow, stony soils with a small amount of organic matter and a low moisture storage capacity. Middle elevations have loam and clay loam forest soils. Soils of the lower elevations are composed of alluvium material of which much of the valley floor is composed.

Upper ridges of the watershed sustain a fir forest with descending elevation, this converts gradually to a pine forest and thence to a sagebrush-grass zone. Riparian areas are heavily vegetated by willows, alders, and other water-loving species.

The Northstar-At-Tahoe development, which occupies a substantial portion of this watershed (75 percent), has been thoroughly described in Sections III through V of this report. Under predevelopment conditions, runoff, and suspended sediment concentration levels were probably quite low. There was some runoff from skid trails and logging roads, but flows did not usually exceed the infiltration capacity of the soils. Surface flows at lower elevations in the watershed were fed by springs and groundwater seepage. Any overland flow was contained in naturally stabilized drainage channels.

In order to determine the change, if any, in sediment yield for the West Martis Creek watershed after the development of Northstar, the environmental monitoring sites shown in Figure VII-1 were established. A schematic diagram shown in Figure VII-2 further depicts the relative layout of significant drainages within the watershed as altered by the Northstar development and the location of the suspended sediment sampling sites.

Streamflow

The following continuous streamflow recording gages were established in the West Martis Creek watershed:

- Gage No. 1. Situated above a 1.22 meter rectangular sharp-crested weir. Located near the Big Springs day lodge on the West Fork of West Martis Creek. Drainage area above this point is 294 hectares and extends to the summit of Mount Pluto at an elevation of 2,620 meters. Approximately 113 hectares of forest land have been cleared for ski trails. Flow over this weir is principally overland flow as spring water is collected via an underground collection system above this point. Groundwater collected by this system is transported either to the water treatment plant or through a bypass structure to the V-notch weir (Site 5).

- Gage No. 2. Situated above a 90 degree V-notch, sharp-crested weir. Located on the East Fork of West Martis Creek above the confluence with the West Fork. The drainage area above this point is 471 hectares. A 200,000 cubic meter storage reservoir is located 2.4 kilometers above this sampling site. All upbasin surface runoff is collected by this reservoir which

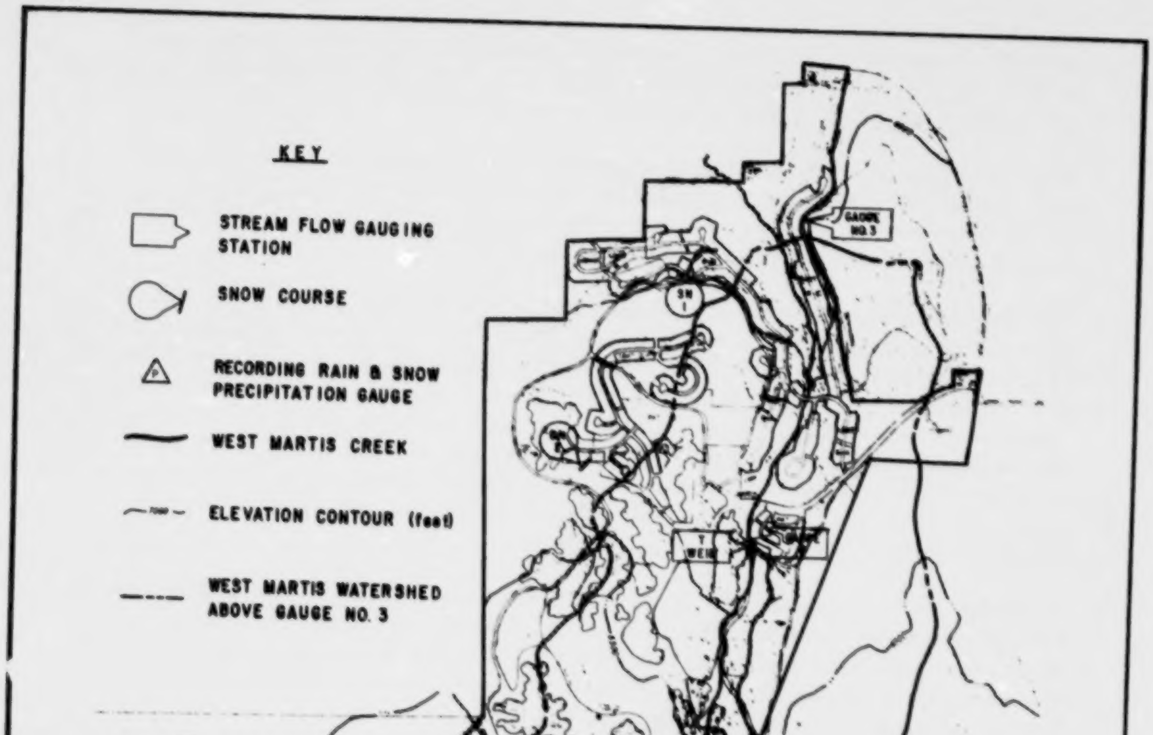
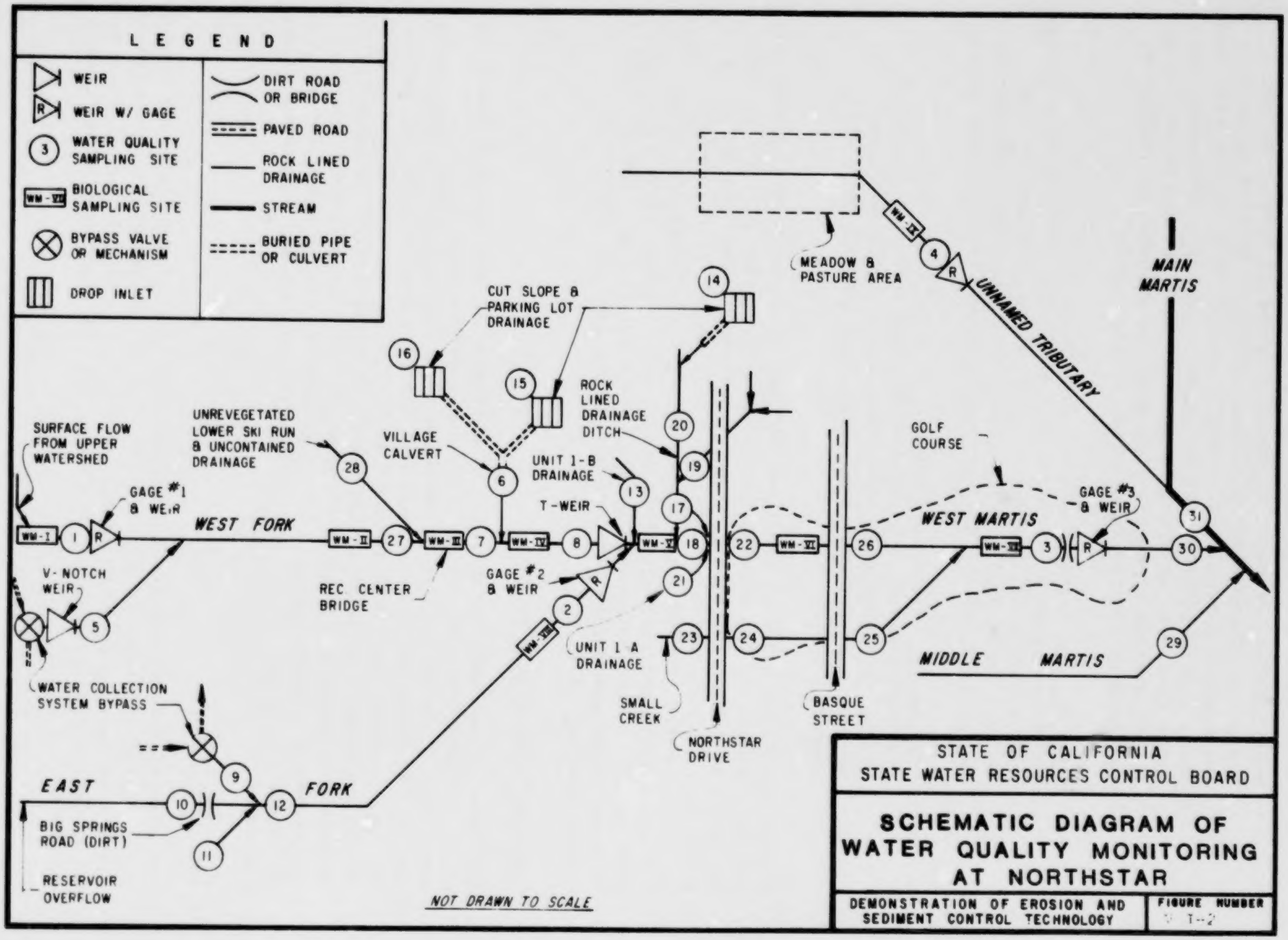

KEY
STREAM FLOW GAUGING STATION
SNOW COURSE
RECORDING RAIN & SNOW PRECIPITATION GAUGE
WEST MARTIS CREEK
ELEVATION CONTOUR (feet)
WEST MARTIS WATERSHED ABOVE GAUGE NO. 3
GAUGE NO. 3
SN 1
SN 2
T WEIR
SN 3
GAUGE NO. 1
V NOTCH
P
SN 4
SN 5
SN 6
0
1/2
1
KILOMETERS

FIGURE VII-1. HYDROLOGIC MONITORING SITES WITHIN WEST MARTIS CREEK WATERSHED (NORTHSTAR).


LEGEND
WEIR
WEIR W/ GAGE
R
3
WATER QUALITY SAMPLING SITE
WM-VII
BIOLOGICAL SAMPLING SITE
BYPASS VALVE OR MECHANISM
DROP INLET
DIRT ROAD OR BRIDGE
PAVED ROAD
ROCK LINED DRAINAGE
STREAM
BURIED PIPE OR CULVERT
MEADOW & PASTURE AREA
WM-IX
4
UNNAMED TRIBUTARY
MAIN MARTIS
CUT SLOPE & PARKING LOT DRAINAGE
16
15
14
ROCK LINED DRAINAGE DITCH
20
19
17
18
21
13
UNIT 1-B DRAINAGE
T-WEIR
GOLF COURSE
GAGE #3 & WEIR
31
30
WEST MARTIS
WM-VII
3
26
22
WM-VI
SURFACE FLOW FROM UPPER WATERSHED
WM-I
1
GAGE #1 & WEIR
WEST FORK
UNREVEGETATED LOWER SKI RUN & UNCONTAINED DRAINAGE
28
WM-II
27
WM-III
7
VILLAGE CALVERT
6
WM-IV
8
WM-V
V-NOTCH WEIR
5
REC. CENTER BRIDGE
GAGE #2 & WEIR
2
WM-VIII
UNIT 1 A DRAINAGE
23
24
25
MIDDLE MARTIS
29
WATER COLLECTION SYSTEM BYPASS
9
SMALL CREEK
NORTHSTAR DRIVE
BASQUE STREET
EAST
FORK
10
12
11
BIG SPRINGS ROAD (DIRT)
RESERVOIR OVERFLOW
NOT DRAWN TO SCALE

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

SCHEMATIC DIAGRAM OF WATER QUALITY MONITORING AT NORTHSTAR

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER
V I-2

only briefly overflows in the springtime of normal and wet years. A groundwater collection system is located above this reservoir. A bypass valve spills excess water to the east fork about one-third of a mile below the reservoir. Extremely low flows have been observed in the east fork at this point due to the limitation of bypass flow from the groundwater collection system when the treatment plant is functioning.

- Gage No. 3. Situated above a 1.83 meter rectangular sharpcrested weir. Located on West Martis Creek below a bridge approximately 0.2 kilometer north of the golf course club house. Total drainage area above this point is 1,308 hectares. The majority of the Northstar development is above this point.
- Gage No. 4. Situated above a 1.22 meter rectangular sharpcrested weir. Located on unnamed tributary to Martis Creek. Drainage area above this point is 220 hectares. Meadow, pasture, and timber areas are located above this sampling point.

Figure VII-3 is a graph of the total monthly flows monitored at Gage No. 3 for the duration of the erosion control project. Also plotted is the monitored extent of the snow pack water content during 1975 and 1976. Based upon the theoretical unimpaired runoff in the Truckee River watershed, water year (October-September) 1975 was 13 percent above the average runoff conditions for this area. On the other hand, water year 1976 was 62 percent below the average runoff conditions. The difference in water years was mainly attributable to the lack of substantial snowfall during 1976.

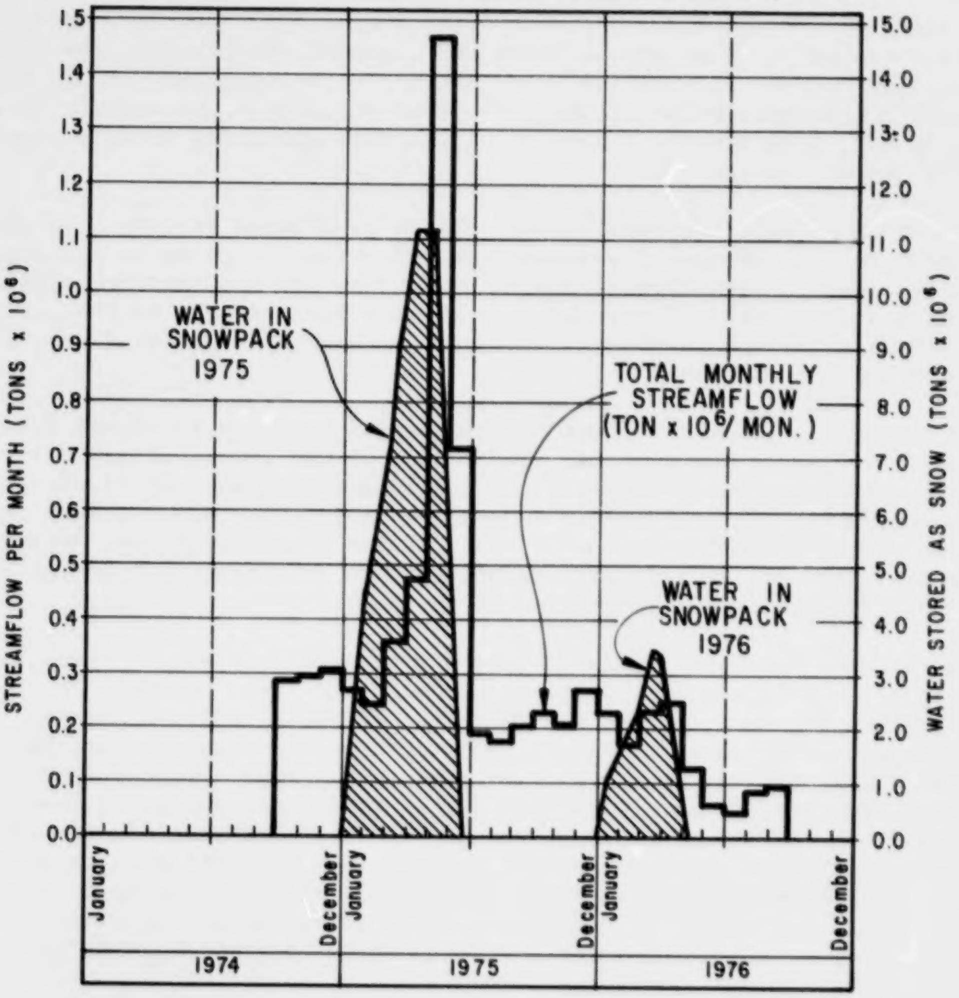
Snow Depth and Water Content

Six snow courses were established at Northstar to monitor snow depth and water content of the snow pack. The snow courses were located approximately in the middle of the succeeding 150 meter elevation contour interval from the top to the bottom of the West Martis Creek watershed. The snow courses were located as close to the center line of the watershed as was practical. Snow depth and snow pack water content measured at each snow course were assumed to represent the average conditions for the particular 150 meter contour elevation interval within which it was situated. A summary of the estimated water content for each snow course is presented in Table C-1, Appendix C.

Precipitation

The electrically heated recording rain-snow gage at Northstar was located at the Water Treatment Plant near the base of the ski hill. The primary purpose of this gage was to identify periods of rainfall for the purposes of the water quality model. This model will be described later in this section.

STREAMFLOW AND SNOW PACK WATER STORAGE AS MEASURED IN WEST MARTIS CREEK WATERSHED FROM OCTOBER, 1974 THROUGH SEPTEMBER, 1976



STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

STREAMFLOW
WEST MARTIS

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER
III-3

The most intense rainfall recorded at Northstar occurred on September 10, 1975. This storm lasted about one hour and had an intensity of approximately 2.5 centimeters per hour. This intensity is indicative of a greater than 20-year storm based upon existing records for the area. The highest nonsnowmelt streamflows were also recorded on this date.

Suspended Sediment Samples

A total of 571 suspended sediment samples were collected at 31 sampling sites around the West Martis Creek and adjacent watersheds. The relative locations of the 31 sampling sites are indicated schematically in Figure VII-2. The description of the individual sampling sites appears in Table C-2, Appendix C. A summary of the data collected at each sampling site appears in Table C-3.

Suspended sediment concentrations clearly fluctuated greatly. In most instances, the suspended sediment concentrations appeared to be roughly proportional to the type of runoff conditions and the instantaneous runoff rate. This relationship was closely investigated in the development of the water quality model for Northstar and will be discussed later in this section.

The highest suspended sediment concentration recorded in runoff from the entire watershed (as measured at Gate No. 3) was 606 parts per million. This sample was collected when the streamflow rate was 625 liters per second during the peak spring snowmelt on April 24, 1975. During this same period, runoff tributary to West Martis Creek from areas disturbed by the Northstar development reached suspended sediment concentrations of 6,029 parts per million (Site 28, 5-22-75).

The highest suspended sediment concentration at Gate No. 3 during rainfall conditions was 526 parts per million. This occurred on September 10, 1975, during the most intense storm recorded for the duration of the erosion control project. The flow rate at Gate No. 3 when the sample was taken was 240 liters per second. Runoff from disturbed areas tributary to West Martis Creek exceeded 8,000 parts per million in certain instances. The maximum recorded suspended sediment concentration in the total runoff from the up-basin ski area on this date was 4,871 parts per million at a flow of 62 liters per second. A summary of the average suspended sediment concentrations monitored at the instream gaging stations on West Martis Creek is presented in Table VII-1.

Analysis of the water quality data shows that suspended sediment concentrations for a given flow rate in the West Martis Creek drainage system are highest during rainstrom events. The lowest concentration occur during periods of low flow when snowmelt or rainstorm runoff is absent. Suspended sediment concentrations typically found during snowmelt conditions, while not as high as during rainstorms, averaged 4-8 times that of low flow conditions.

TABLE VII-1

AVERAGE SUSPENDED SEDIMENT CONCENTRATIONS
RECORDED AT INSTREAM GAGING STATIONS
ON WEST MARTIS CREEK

	AVERAGE SUSPENDED SEDIMENT CONCENTRATION (ppm)*		
	Gage No. 1	Gage No. 2	Gage No. 3
Low Flow	4.2 (12)	4.2 (13)	7.9 (13)
Rainfall	944.0 (7)	53.7 (16)	115.0 (20)
Snowmelt	33.4 (16)	28.9 (36)	28.5 (43)

* number of samples taken indicated in parenthesis

Benthic Macroinvertebrates

Biological sampling stations at the Northstar development were selected to illustrate effects on aquatic benthic macroinvertebrates by specific local land disturbances. The following biological sampling stations, located as shown in Figures VII-1 and VII-2, were established on West Martis Creek:

- Station WM-I. An unnamed stream at Big Springs about 15 meters upstream of the main ski lodge. The station was discontinued after the September 1974 sampling period when it was covered to improve ski safety. This station was chosen as the site furthest above development in the watershed. Although most of the ski area is above this station, there is little adverse effect since much of the runoff from the ski area percolates into the ground in underdrains installed for the Northstar domestic water system and here enters the stream.

- Station WM-II. About 15 meters upstream of the water storage tanks and above the uppermost area of condominiums on the West Fork of West Martis Creek. This station was chosen to represent the macrobenthic community just above the Northstar development complex and was thought to be a community relatively "undisturbed" by pollutants.

- Station WM-III. Just above the first major culvert (Village Culvert) discharge on the West Fork of West Martis Creek. This station represents the macrobenthic community just above the discharge of the Village Culvert (Village Center commercial area). Though this station would receive runoff from unrevegetated sections of the ski area and uncontrolled drainages, it was intended to serve as a reference station to compare with Station WM-IV.

- Station WM-IV. Just below the discharge point of the Village Culvert on the West Fork of West Martis Creek. It was anticipated that the discharges from this culvert would have a great impact on the macroinvertebrates at Station WM-IV due to the heavier loading of silts and sediments and parking lot runoff (oils and grease).

- Station WM-V. About 50 meters upstream of Northstar Drive Stream crossing on West Martis Creek. This station was established as a reference station for Station WM-VI.

- Station WM-VI. About 15 meters downstream of Northstar Drive Stream crossing on West Martis Creek. This station is immediately below the discharge from two large drainage ditches from condominiums and parking lots and is below an extensive fill area on Northstar Drive. The roadway fill shows signs of erosion into West Martis Creek. The macrobenthos at Station WM-VI were expected to be more adversely affected from local surface runoff than were the macrobenthos at Station WM-V which was more remote from direct influences of point discharges to West Martis Creek.

- Station WM-VII. Just upstream of Gage 3. This station was assumed to be adversely affected as it received runoff from the entire Northstar development, including the golf course which was constructed and completed during this study.

- Station WM-VIII. Just upstream of Gage 2 on the East Fork of West Martis Creek. This station was to serve as a reference station to compare with "reference" stations on West Martis. As the only unnatural sources of silt and sediment are from a dirt road crossing 2.4 kilometers upstream, it was originally assumed that this station represented a "natural" or "clean-water" community. Unfortunately, however, the East Fork of West Martis is a controlled flow and it is possible that this condition could affect the benthic population.

- Station WM-IX. About 100 feet above Gage 4. Station WM-IX is the other "clean-water" or "normal" community reference station in this unnamed tributary to Martis Creek. A limited number of cattle are pastured about one-half mile upstream. There is no development or unnatural soil disturbance such as roadways, buildings, etc. in this watershed.

The results of the benthic macroinvertebrate monitoring program are summarized in Table VII-2.

In all of the five sampling seasons, only one season showed any significcant differences between stations of the standing crop estimate (number/meter^2). This occurred at Stations WM-III and WM-IV sampled on September 1974. As can be seen in the graph (Figure VII-4), all orders Insecta and Oligochaeta had a significantly lower population at Station WM-III, below the discharge of the Village Culvert, than the reference Station WM-III, which is upstream of the Village Culvert. The total number of families declined from 21 above to 18 below the Village Culvert. However, this decrease in families is not significant as the diversities of these two communities are not significantly different. The diversities recorded there were also two of the highest diversity indices recorded during the entire West Martis study (Table VII-2).

The September 1974 macroinvertebrate collection could not be correlated to water quality as there was no background data available at that time. However, the significant differences in standing crops between Stations WM-III and WM-IV were obviously due to discharges from the Village Culvert. Accumulated sediment in the rock lined ditch below the culvert outlet suggested that discharges of suspended sediment did occur due to previous construction activities, winter road sanding activities, and exposed road cuts in the parking lot area.

The July 1975 collection revealed a general decrease in species abundance and standing crop from Station WM-III to Station WM-VI. This is most likely related to the steady increase in average suspended sediment concentrations between Gage No. 1 and all the water sampling points through to Station WM-VI (from 18.8 parts per million to 73.3, respectively, during the first six months of 1975).

The December 1975 collection revealed some perturbations at Stations WM-II, WM-III, and WM-IV, where low diversities were found. Though water quality sampling was limited to spot sampling during low flows and runoff events after July 1975, siltation problems were still evident. High runoff suspended sediment concentrations were observed in the upper watershed near the affected stations. Drainage from the T-1 lift above the Village Culvert had an average of 2,866 parts per million and a maximum of 8,339 parts per million, while Village Culvert averaged 688 parts per million and a maximum of 1,093 parts per million during runoff events. Downstream near Station 4, the average runoff conditions were 1,791 parts per million, with a maximum of 6,757 parts per million. In previous studies(3), runoff conditions of lower concentrations (100-1,200 parts per million) had a far more severe impact on the macroinvertebrate community than is seen in this study of the West Martis Creek watershed as affected by the Northstar development.

TABLE VII-2

RESULTS OF SURBER SAMPLING AT NINE STATIONS IN THE WEST MARTIS CREEK WATERSHED

Units	Date of Collection	WM-I	WM-II	WM-III	WM-IV	WM-V	WM-VI	WM-VII	WM-VIII	WM-IX
Number/m^2	09-16-74	2731	619	2917	931	1728	2543	2193	885	5718
	07-31-75		785	576	556	461	386	1611	1028	2536
	12-08-75		1002	850	651	1013	1796	821	514	500
	06-03-76		995	1164	1104	874	1485	1364	1389	1806
	10-13-76		1212	664	748	1662	1336	1578	1887	1410
Number of families	09-16-74	16	19	21	18	17	21	20	20	20
	07-31-75		20	21	19	16	14	22	20	20
	12-08-75		19	17	17	24	20	20	19	17
	06-03-76		18	21	16	16	22	14	22	13
	10-13-76		15	12	19	16	14	20	17	16
Diversity	09-16-74	1.905	2.785	2.829	2.757	2.439	2.137	2.257	2.476	2.296
	07-31-75		2.012	2.334	2.111	2.211	2.197	2.059	2.492	2.043
	12-08-75		1.689	1.925	1.960	2.264	2.187	2.293	2.515	2.026
	06-03-76		1.689	1.958	1.078	2.289	2.520	1.554	2.038	1.426
	10-13-76		2.437	2.047	2.127	1.853	2.038	2.084	2.056	1.705
Evenness	09-16-74	0.48	0.65	0.64	0.66	0.59	0.48	0.52	0.57	0.53
	07-31-75		0.46	0.53	0.50	0.55	0.58	0.46	0.57	0.47
	12-08-75		0.40	0.47	0.48	0.49	0.50	0.53	0.59	0.49
	06-03-76		0.46	0.44	0.27	0.57	0.56	0.41	0.46	0.38
	10-13-76		0.62	0.57	0.50	0.46	0.57	0.48	0.50	0.43

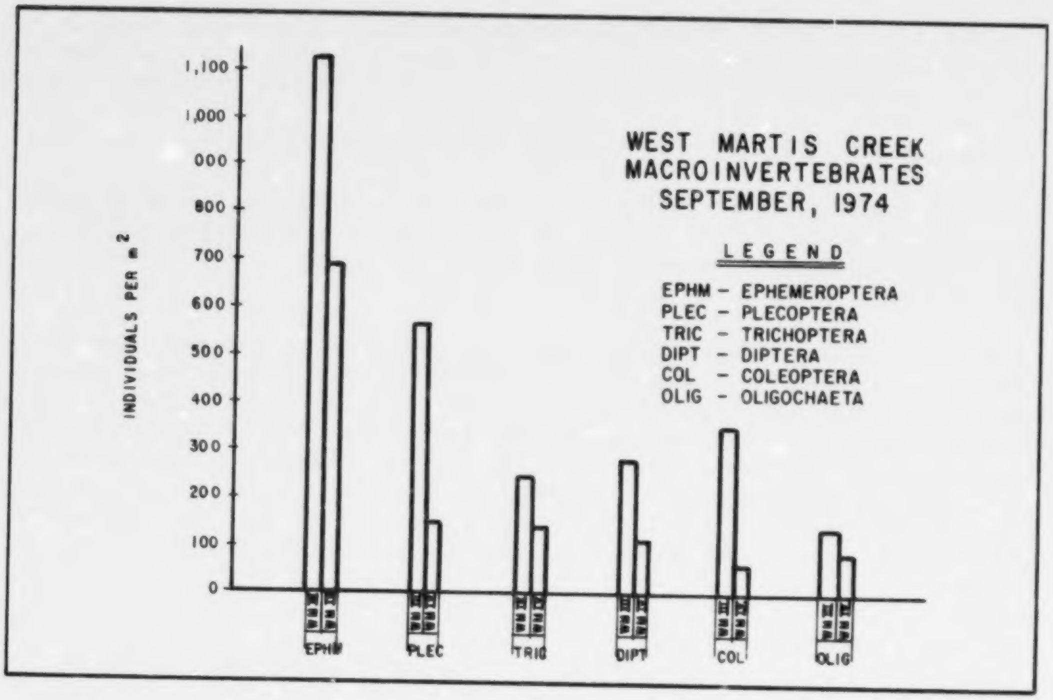


Figure VII-4. West Martis Creek Macroinvertibrates, September 1974.

The June 1976 collection revealed unusually low diversities. This was probably due to the low flows (due to drought conditions) and lack of flushing action which created deposits of sediment. Sediment deposits were also seen along the stream banks in the November 1976 collection, but not so heavy as in the June collection period. There were three small rainfall events in the fall which could have aided in flushing some excess sediments downstream. This could be seen in the November 1976 collection as diversity indices and evenness estimates improved.

Although Surber sampling stations for benthic macroinvertebrates were established to monitor areas in the Northstar development where sediment and erosion problems were suspected to occur, the macrobenthic community only suffered minor pertubations. The results did not illustrate the impact which has been observed in other studies which have documented the impact of eroded sediments on benthic macroinvertebrates(3,36,37). The primary reason for an absence of perceptible impacts on the macrobenthic community is the extremely low sediment yield for the Northstar development. The suspended sediment load computer simulation program, discussed later in this section, has shown that the Northstar development has resulted in a less than one-fold increase in suspended sediment yield above natural background levels. While this increase has been perceptible from a water quality monitoring standpoint, it does not appear to have resulted in an adverse impact on the macrobenthic community.

D. WATER QUALITY OF LONELY GULCH CREEK (RUBICON PROPERTIES)

The watershed of Lonely Gulch Creek has 275 hectares with a mean annual precipitation of 104 centimeters mostly as snow. The stream follows a moderately steep course until it reaches Lake Tahoe at Rubicon Bay (Figure VII-5).

The soils of the watershed are entirely a decomposed granite formation, except at lower elevations near the lakefront which consists of glacial moraines. The upper reaches of the study area are dominated by moderately deep to shallow, coarse textured rocky soils over weathered granitic bedrock; the lower reaches by a zone of gravelly and stony soils with pans formed in glacial moraines and outwash. Adjacent to the lake deep soils on alluvial fans and outwash are found. Most of the watershed is covered with a relatively dense mixed coniferous forest down to the lakeshore.

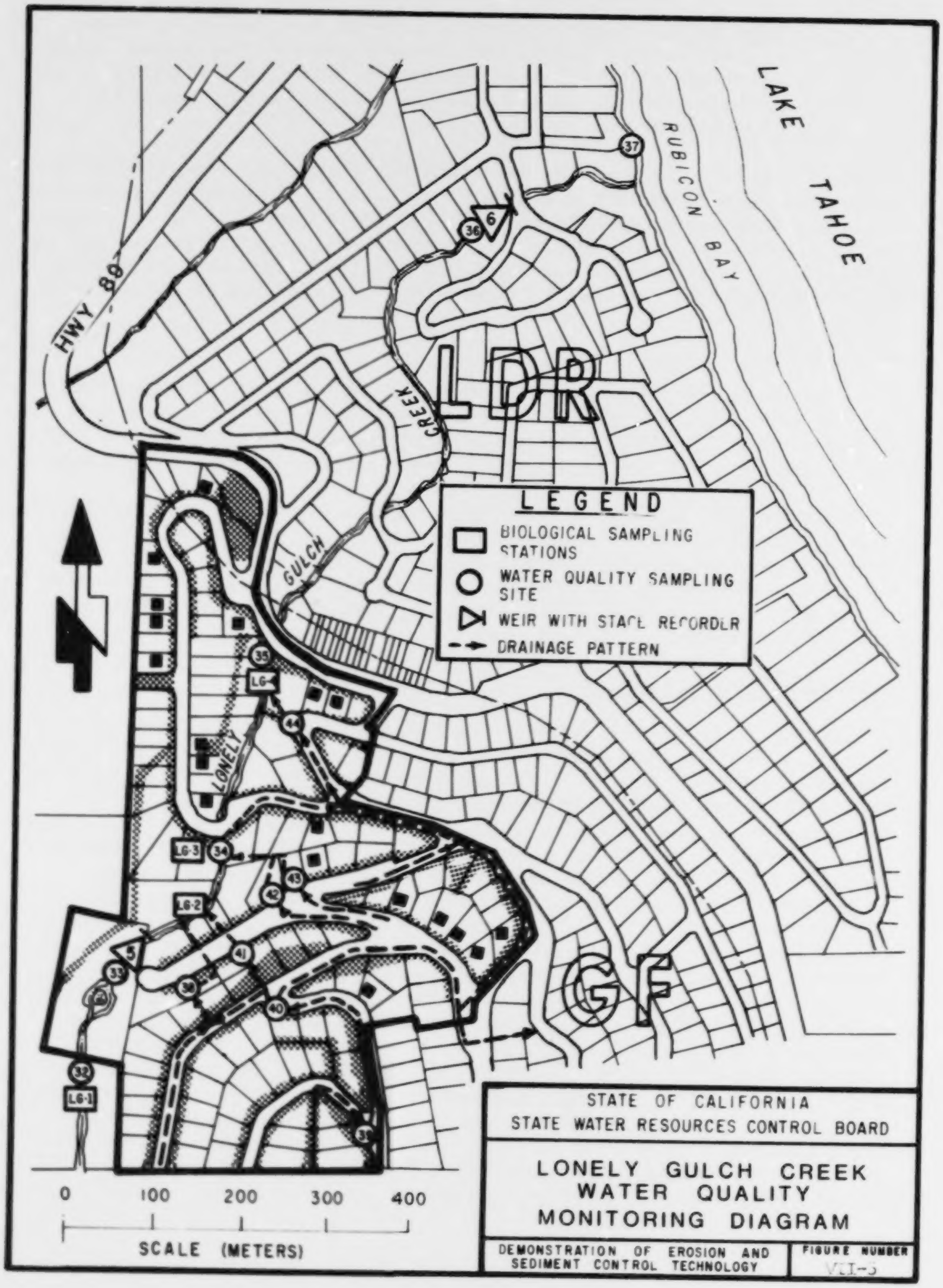
Before it receives any discharge from disturbed lands, Lonely Gulch Creek flows into a small reservoir used for domestic water supply. Below this, the Creek flows through the Rubicon Properties Subdivision, the main land disturbance in the watershed. Steep roadcuts (30 to 45 percent, up to 25 meters long) and homesite excavations have created an accelerated source of fluvial sediment. Rubicon Properties is thoroughly described in Section VI of this report.

Additionally, during the spring and summer of 1973, extensive sewer construction occurred in the Rubicon development and along Lonely Gulch Creek. The stream bank was altered to accommodate the sewer line and the line also crossed the Creek at the lower end of the Subdivision. The locations of the various streamflow gages, water quality sampling sites, biological sampling stations, and the precipitation gage are shown in Figure VII-5. These monitoring locations were established to determine the comparative sediment yield and water quality impacts of the undisturbed upper watershed ($2.37 km^2$) with the heavily disturbed lower watershed ($0.38 km^2$).

Streamflow

The following continuous recording gages were established in Lonely Gulch Creek to monitor streamflow:

- Gage No. 5. Situated above a 1.22 meter rectangular sharp-crested weir. Located just below the domestic water supply storage reservoir on Lonely Gulch Creek. Drainage area above this point is 237 hectares of undisturbed watershed.


LAKE TAHOE
RUBICON BAY
HWY 89
37
6
36
LDR
CREEK
GULCH
LONELY
LEGEND
BIOLOGICAL SAMPLING STATIONS
WATER QUALITY SAMPLING SITE
WEIR WITH STAGE RECORDER
DRAINAGE PATTERN
35
LG-4
44
LG-3
34
43
42
LG-2
5
41
33
38
40
GF
32
LG-1
39
0
100
200
300
400
SCALE (METERS)

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LONELY GULCH CREEK WATER QUALITY MONITORING DIAGRAM

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER VII-5

- Gage No. 6. Situated above a 1.22 meter rectangular sharp-crested weir. Located 180 meters above mouth of Lonely Gulch Creek and below all major land disturbance in the Lonely Gulch Creek watershed. Total drainage area above Gage No. 6 is 75 hectares.

Figure VII-6 is a graph of the total monthly flows monitored at Gage No. 5 during the periods which the gage was maintained. Substantial amounts of water are diverted above Gage No. 5 for domestic water supply for Rubicon Properties Subdivision. As was true in West Martis Creek, streamflow in Lonely Gulch Creek in 1976 was substantially lower than 1975 streamflow due to the considerably reduced winter precipitation levels during 1976.

Precipitation

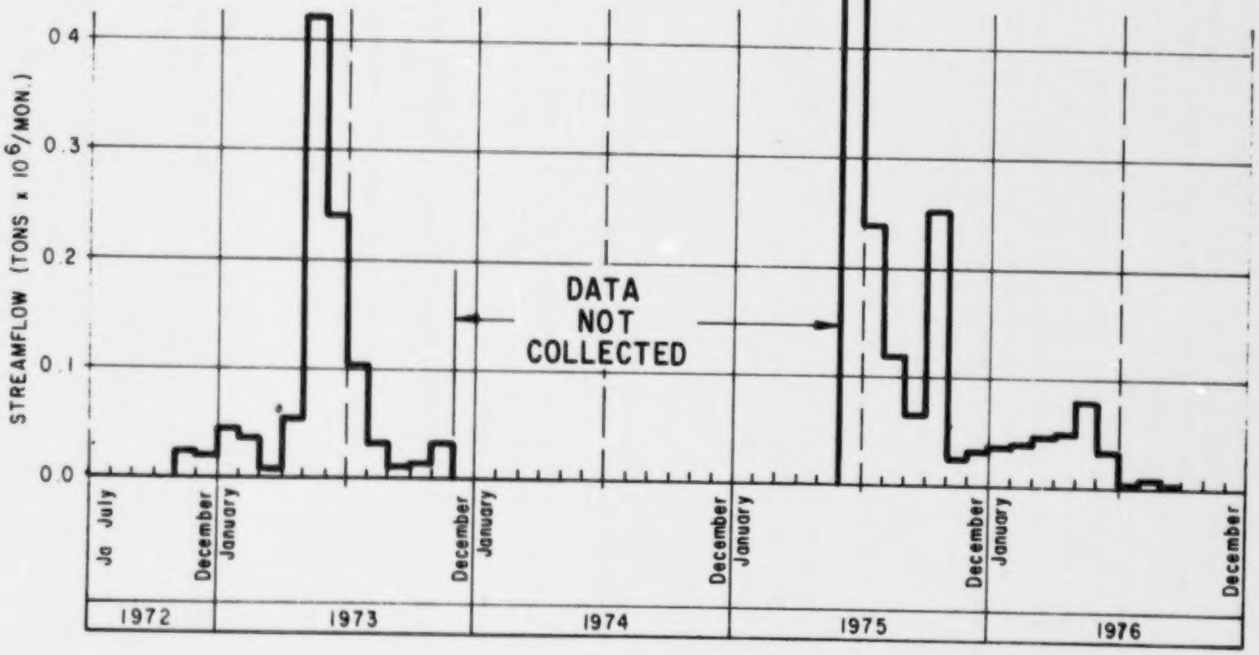
The propane heated recording rain-snow gage at Rubicon Properties was located near the upper water supply storage tank off of Highland Drive. As was true at Northstar, the primary purpose of the precipitation gage was to identify periods of rainfall for use with the water quality model.

Although several rainstorms occurred in the Lonely Gulch Creek watershed, none of the observed storms were as intense as the one recorded at Northstar on September 10, 1975. The most intense storm of record occurred on August 16, 1976, with a maximum intensity of 1.0 centimeter per hour. Total rainfall for a two-day period starting the previous day was 8.25 centimeters.

Suspended Sediment Samples

A total of 301 suspended sediment samples were collected within the Lonely Gulch Creek watershed during the periods of September 1972 through September 1973 and June 1975 through September 1976. The relative locations of the sampling sites are indicated in Figure VII-5. Descriptions of the individual sampling sites appear in Appendix C, Table C-4. A summary of the data collected at each site appears in Table C-5. Variations in the suspended sediment concentration were extremely erratic due to the extensive concentrated disturbances and erosion sources in an extremely small watershed. For example, small amounts of eroded sediment might build up in one location after a series of small runoff events. The initial stages of a subsequent large runoff event would then have an astronomical suspended sediment concentration. The highest concentration of suspended sediment in runoff within Rubicon Properties Subdivision was 231,000 parts per million. The highest instream sediment sample was collected where Lonely Gulch Creek passes under State Highway 89 with a concentration of 15,200 parts per million. In all cases, the suspended sediment concentrations were dramatically higher during periods of rainstorm runoff than during snowmelt runoff. It was estimated that at the peak of a two-day, 5.54-centimeter rainstorm on October 10 and 11, 1975, that up to 15 metric tons of

STREAMFLOW AS MEASURED IN
LONELY GULCH CREEK AT GAUGE # 5



FROM
NOVEMBER, 1972 THROUGH NOVEMBER, 1973
AND FROM
JUNE, 1975 THROUGH SEPTEMBER, 1976.

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

STREAMFLOW
LONELY GULCH CREEK

DEMONSTRATION OF EROSION AND
SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER
VII-6

suspended sediment were being discharged to Lonely Gulch Creek in a single hour.

These high rates of sedimentation have devastated Lonely Gulch Creek. Above the first sediment discharge point from Rubicon Properties Subdivision, Lonely Gulch Creek has the appearance of a small pristine mountain stream. However, by the time it has wound its way down through the Subdivision, Lonely Gulch Creek is choked by deposited sediments. The deposition is evidenced to some degree by the reduction of recorded suspended sediment concentrations as the stream gradient decreases towards Lake Tahoe. This is due to increased settling and suspended sediment deposition. The highest suspended sediment levels on Lonely Gulch Creek were at Rubicon Glen Drive (Site 34) and Highway 89 (Site 35), less than 100 meters downstream from the most severe sediment discharges from Rubicon Properties Subdivision and about 900 meters above Lake Tahoe. By the time a slug discharge of suspended sediment to Lonely Gulch Creek has reached Gage No. 6 (Site 36), only 150 meters above Lake Tahoe, suspended sediment concentrations are usually quite diminished.

A summary of the average suspended sediment concentration monitored at the instream sampling stations above and below Rubicon Properties Subdivision is presented in Table VII-3.

Benthic Macroinvertebrates

The following biological sampling stations, located as shown in Figure VII-5 were established on Lonely Gulch Creek:

- Station LG-1. 100 meters above all road and land development disturbances. The Creek in this area is typical of a Sierra Mountain forest stream.
- Station LG-II. 70 meters above Station LG-III and approximately 200 meters below Station LG-1. It is above a large swale which drains the steeper and more extensive roadcuts of Rubicon Properties. Although this station receives minor drainages from roadcuts and fills, it serves as a "reference" station for Station 3.
- Station LG-III. 50 meters below the start of road and subdivision disturbance and about two meters below the first three drainage swales which collect most of the street runoff from the roadcuts.
- Station LG-IV. 25 meters above State Highway 89 and 250 meters below Station LG-III. It was below most of the drainage swales which collect surface runoff from Rubicon Properties.

As in a previous study of Lonely Gulch Creek(3), the downstream stations had lower standing crop estimates (Total No. Individuals/m^2), lower

TABLE VII-3

AVERAGE SUSPENDED SEDIMENT CONCENTRATIONS RECORDED AT INSTREAM SAMPLING SITES IN LONELY GLUCH CREEK ABOVE AND BELOW DEVELOPMENT

	AVERAGE SUSPENDED SEDIMENT CONCENTRATION (ppm)*	
	ABOVE DEVELOPMENT	BELOW DEVELOPMENT
Low Flow	1.3 (38)	12.9 (36)
Rainfall	20.8 (18)	1798.1 (33)
Snowmelt	9.1 (41)	434.6 (45)

* number of samples taken indicated in parenthesis

diversities, and, in most cases, lower species abundance than the control Station LG-1 for all periods of collection. "Reference" Station LG-II also contained a higher standing crop estimate and a equal or higher species abundance than downstream Station LG-III for all periods of collection. The results of the benthic macroinvertebrate monitoring program conducted in the Lonely Gulch Creek watershed are summarized in Table VII-4. Figures VII-7, 8, 9, and 10 graphically depict the standing crop estimates for the July 1975, December 1975, June 1976, and November 1976 sampling periods respectively. The increasing impacts, as one moves downstream, are clearly indicated by the reduced numbers of individuals in representative orders at each successive downstream station.

The decrease in species abundance, diversity, and standing crop estimates in the downstream macroinvertebrate communities is well correlated with the downstream increase in suspended sediment for the July and December 1975 collections. Runoff into Lonely Gulch Creek below Station LG-II ranged from 1,500 - 250,000 parts per million in drainage ditches and culvert outlets. However, during the December 1975 - June 1976 sampling period, no significant rainfall events took place to create the heavy silt laden runoff as seen in previous sampling. The snowmelt produced little runoff and low flows due to the very light winter. Consequently,

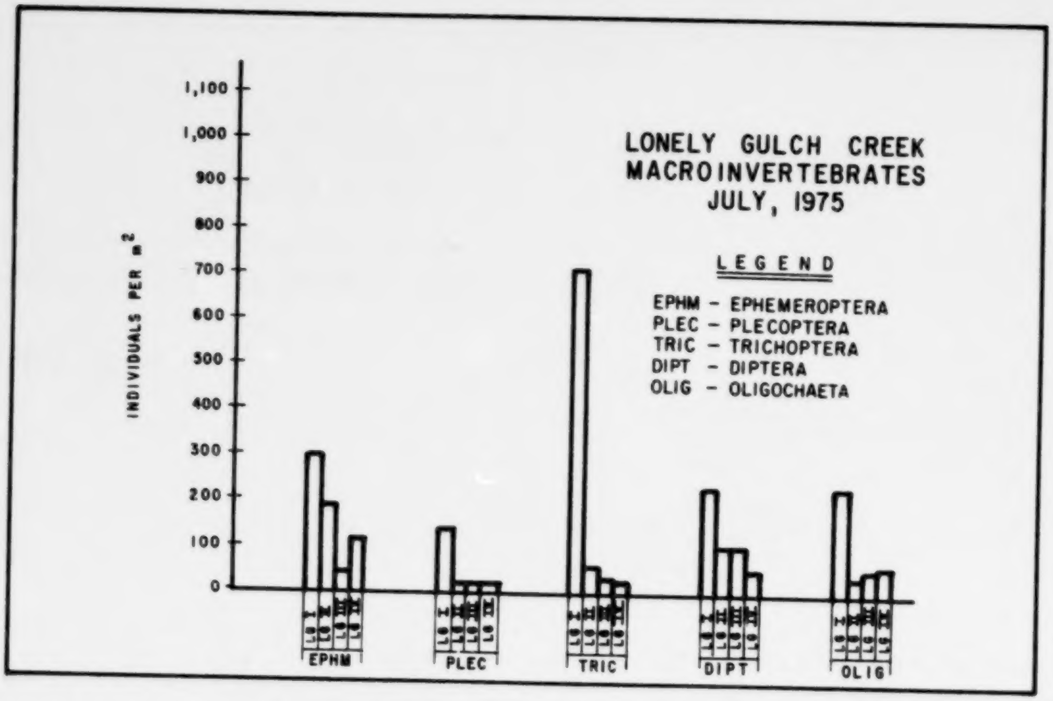


Figure VII-7. Lonely Gulch Creek Macroinvertebrates, July, 1975.

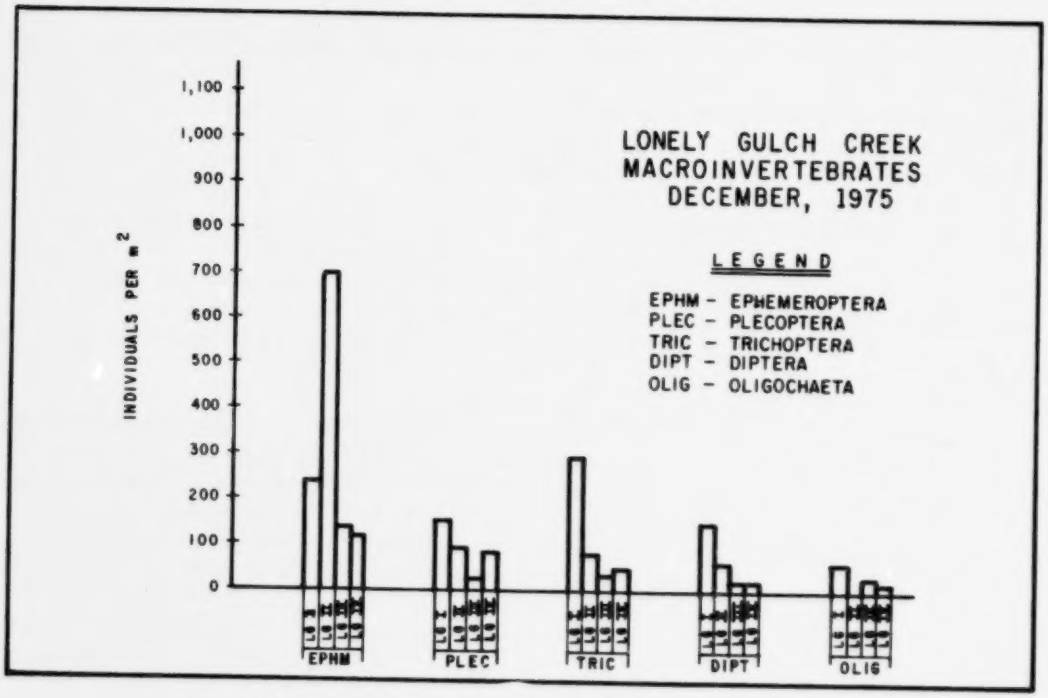


Figure VII-8. Lonely Gulch Creek Macroinvertebrates, December, 1975.

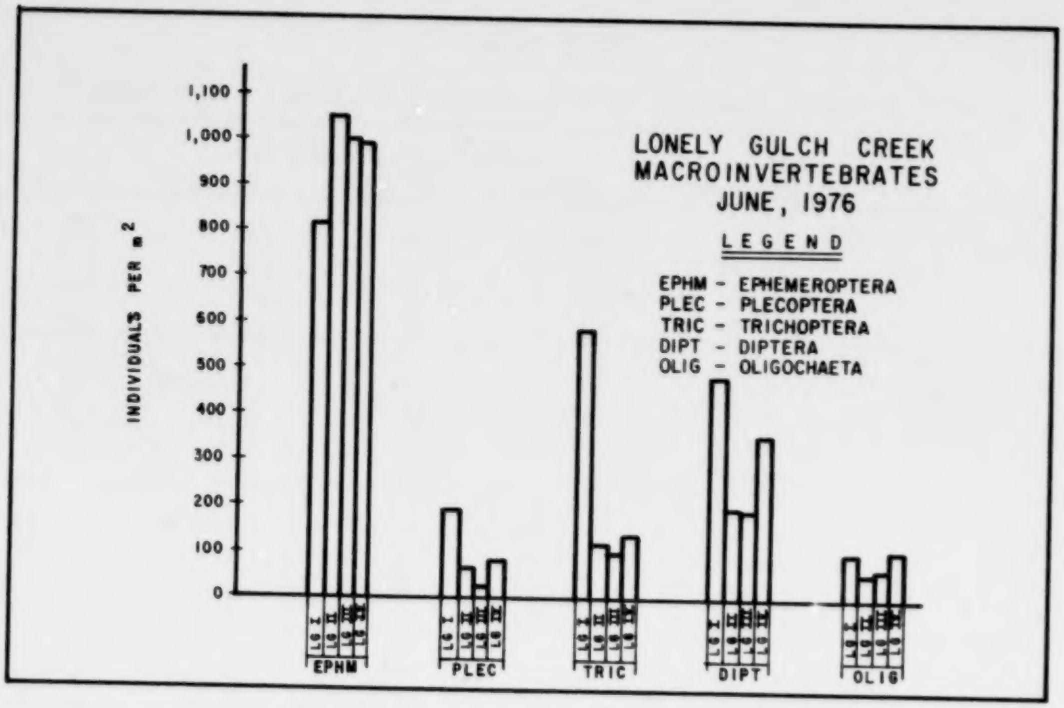


Figure VII-9. Lonely Gulch Creek Macroinvertebrates, June, 1976.

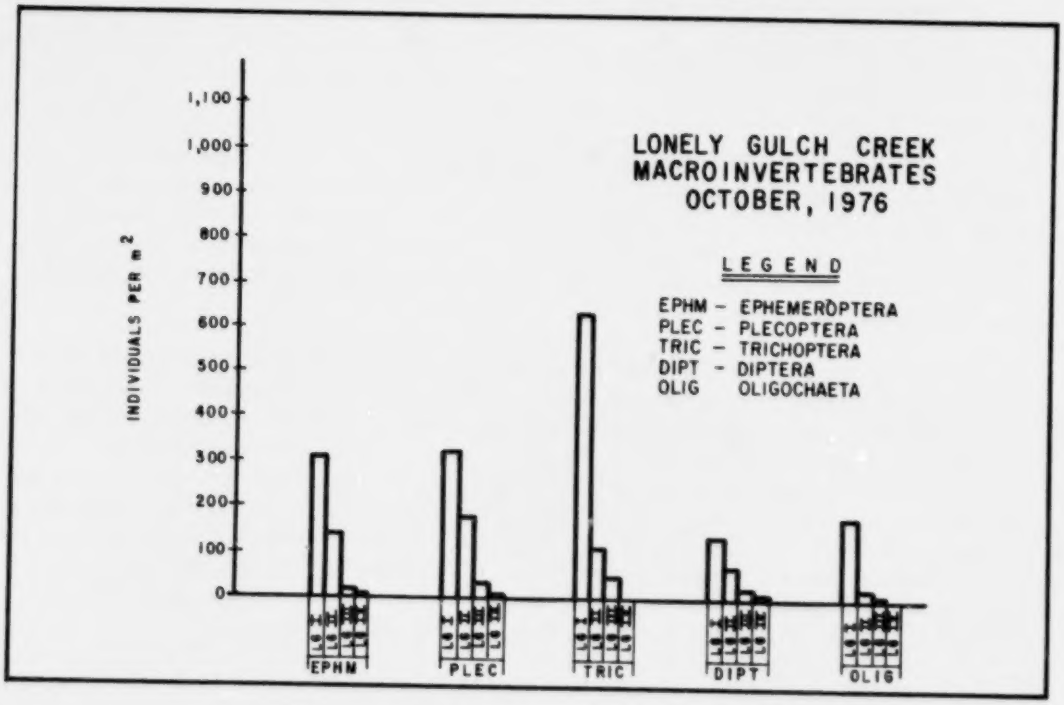


Figure VII-10. Lonely Gulch Creek Macroinvertebrates, October, 1976.

TABLE VII-4

RESULTS OF SURBER SAMPLING AT FOUR STATIONS ON LONELY GULCH CREEK

UNITS	DATE OF COLLECTION	LONELY GULCH STATIONS			
		LG-I	LG-II	LG-III	LG-IV
Number/m^2	7-08-75	1542	398	244	267
	12-08-75	1321	945	245	277
	6-18-76	2125	1465	1366	1652
	10-04-76	1560	496	99	19
No. of Families	7-08-75	20	14	11	09
	12-08-75	19	12	12	12
	6-18-76	14	13	13	14
	10-04-76	14	14	09	04
Diversity	7-08-75	2.497	1.962	1.988	1.913
	12-08-75	2.247	1.464	1.996	2.077
	6-18-76	2.150	1.582	1.405	1.846
	10-04-76	2.207	2.072	1.938	1.352
Evenness	7-08-75	0.58	0.51	0.57	.60
	12-08-75	0.53	0.41	0.56	.58
	6-18-76	0.56	0.43	0.38	.48
	10-04-76	0.58	0.54	0.61	.67

low flows and low suspended sediment created few interstation differences between species abundance and standing crop estimates for the June 1976 collection. Station LG-I was decreased to only 14 families probably because the low flow drought conditions eliminated the rarer families. Changes in water level or current have been known to change whole communities (38,39,40).

In the four month period preceding the November 1976 sampling period, three rainstorms produced runoff in drainage ditches which discharged just above Station LG-III producing an average runoff concentration of 6,600 parts per million and a maximum of 15,157 parts per million in Lonely Gulch Creek at Station LG-III. The drainage ditch above Station LG-IV had an average runoff concentration of 10,211 parts per million and a peak value of 32,756 parts per million. Lonely Gulch Creek at Station LG-IV had an average runoff condition of 7,183 parts per million of suspended sediment. The results of these storms, runoff, and low baseline flows could be seen in the stream substrate.

During all sampling periods, Station LG-1 had the "normal" substrate of cobble, pebble, gravel, and some sand while Station LG-II had the same except for a slightly higher percentage of sand and some silt. At Station LG-III, the cobble was "cemented" in by sand and silt while at Station LG-IV it was completely overwhelmed by a silty sand with the cobble, pebble, and gravel buried beneath. The effect of these substrate conditions on the macrobenthic community is obvious. The macrobenthic community at Stations LG-III and LG-IV were almost eliminated in the November 1976 sampling period. The need for sound land management and effective erosion control practices is amplified by the results of this study. High suspended sediment concentrations coupled with low flow conditions have created an adverse effect on the macroinvertebrate community of Lonely Gulch Creek and nutrient contributions from suspended sediment.

The ongoing erosion control work in the Lonely Gulch Creek watershed at Rubicon Properties will be monitored in the future for its effectiveness in stream recovery and lessening sediment loading to Lake Tahoe.

E. WATER QUALITY MODELING OF SUSPENDED SEDIMENT TRANSPORT

In order to determine mass emission rates for suspended sediment from both the Northstar and Rubicon Properties developments, a simple "model" to predict these loads was sought. Suspended sediment transport at both the project sites had a seemingly proportional relationship with the amount of streamflow. This first task was to determine the type of relationship that would reliably predict the suspended sediment concentration for a given streamflow. Because continuous streamflow recordings were available at three streamflow gages in the West Martis watershed and two in Lonely Gulch Creek, such relationships would define the amount of suspended sediment transported past each gage for any given period of time.

Admittedly, such an approach is simplistic, as suspended sediment levels can be quite different for a given flow level depending on whether a sample is taken at the beginning or end of a runoff period. Nonetheless, the project staff felt that a well correlated average relationship between these extremes would yield acceptable estimates of overall suspended sediment mass emission rates. Certainly such relationships, if reasonably well correlated, would yield acceptable estimates for comparative purposes (i.e., post-development versus pre-development, or upstream versus downstream sediment loads).

Initially, one mathematical expression relating suspended sediment to streamflow was sought for each streamflow gaging station. However, correlations for such a single expression were generally extremely low. From this point, the project staff sought to define more than one expression at each gaging station depending on the varying types of runoff. The following runoff types were identified and defined:

- Rainstorms. These runoff periods were defined by the recording precipitation gages at Northstar and Rubicon Properties. An added requirement of these periods was that they must cause a perceptible rise in at least one of the recording streamflow gages.

- Stage I Snowmelt. These periods were defined as beginning when snow first remained without melting at the start of the winter season and ending when the maximum runoff period was reached in the spring. Early snowstorms which melted immediately during the fall were treated as rainstorms.

- Stage II Snowmelt. These periods began after the peak runoff period was reached in the spring (i.e., the end of Stage I) and ended when diurnal streamflow fluctuations from snowmelt were no longer significant and runoff approached low flow levels.

- Low Flow. These periods occurred from the end of Stage II snowmelt until the commencement of Stage I snowmelt the following winter, except as interrupted by snowmelt conditions.

In all cases, suspended sediment concentrations were assumed to never be less than that defined by the mathematical expression for low flow. The various mathematical expressions defining suspended sediment concentrations for a particular flow type were derived by means of linear regression analysis. In all cases, linear regression gave better correlations than did exponential, power law, or logarithmic curve fits.

Once the suspended sediment versus flow relationships were established with well defined periods of applicability, they were combined with previously digitized streamflow data to produce estimates of suspended sediment concentrations and sediment mass emission rates on a daily basis. At each streamflow gage and each streamflow type, the data was summarized on a daily, monthly, and, where possible, yearly basis. These summarizations for each gage appear in tabular form in Appendix C, Tables C-8 through C-13.

WEST MARTIS CREEK

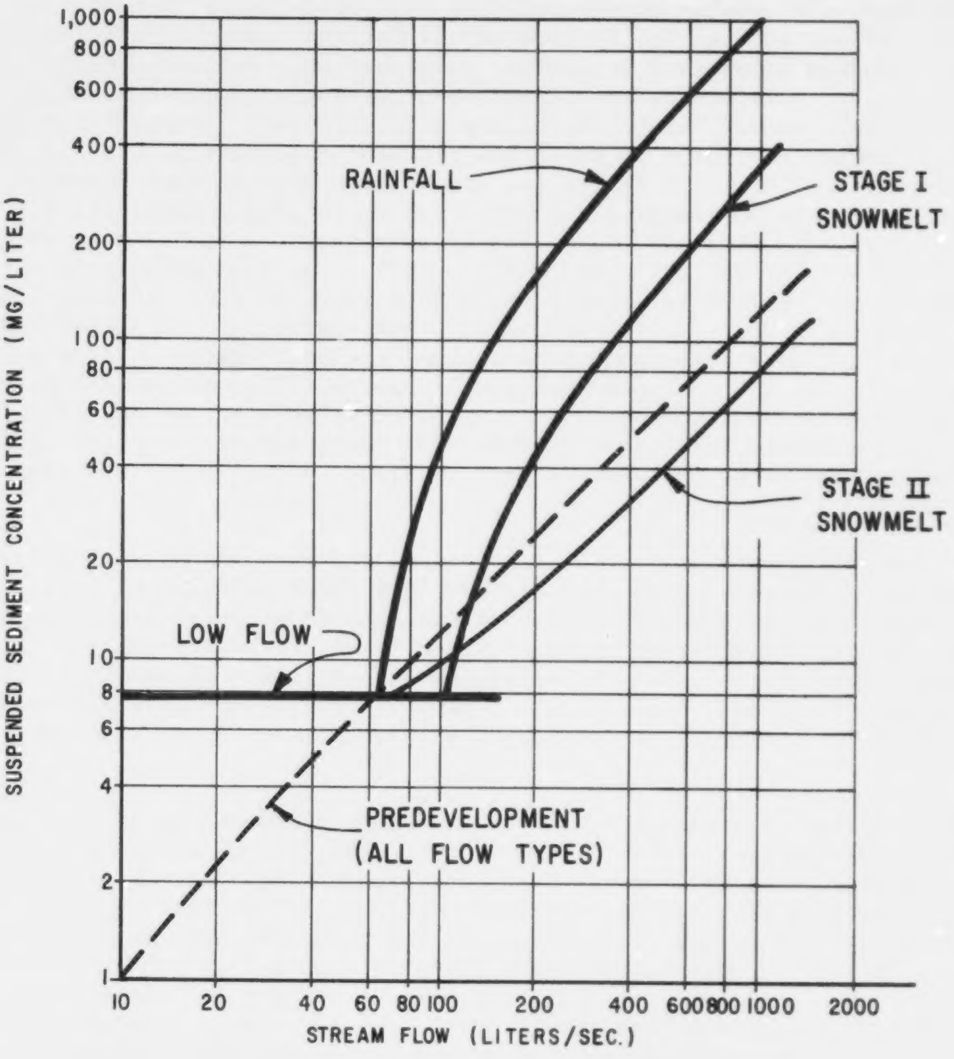
The basic equations correlating suspended sediment concentration (SS mg/l) with streamflow (Q l/sec) for each of the streamflow gages are given in Table VII-5. In most instances, confidence levels based on a Student's t-distribution analysis were greater than 99 percent. In all cases, well correlated relationships could not be developed for low flow conditions; thus, for low flow, the average recorded suspended sediment concentration was used irrespective of streamflow. This is a reasonable simplification due to the relatively insignificant sediment concentration found during low flow periods. Fluctuations in the assumed suspended sediment concentrations during low flow period yield an insignificant variation in overall calculated sediment mass emission rates.

Considerable problems were encountered in trying to determine suspended sediment relationships for predevelopment conditions in the West Martis Creek watershed. Only scattered water samples had been taken at a low frequency and usually during only low flow conditions. However, at the site designated Gage No. 3 (Site No. 3) for the erosion control project, nine samples at various streamflow rates had been collected prior to July 1971. This was before extensive construction activities began at Northstar. Unfortunately, turbidity (JTU) was the only parameter recorded which could be related to suspended sediment concentration levels. To provide a reliable substitute for direct suspended sediment samples, a linear regression analyses was performed to correlate turbidity (JTU) with suspended sediment (mg/l) for 28 samples collected at Gage No. 3 between October 25, 1974, and May 29, 1975. The data correlated extremely well with a confidence level greater than 99.99 percent, as determined by a Student's t-distribution analysis. Thus, using this suspended sediment versus turbidity relationship, suspended sediment concentrations were estimated for the nine predevelopment samples. The maximum estimated suspended sediment concentration developed in this manner was 73 mg/l for a predevelopment rainstorm (November 25, 1970) sample taken at Gage No. 3 when streamflow was 340 l/sec. The turbidity recorded at this time was 12.0 JTU.

A graphical presentation of the suspended sediment concentration versus streamflow relationships for Gage No. 3 is shown in Figure VII-11. The relationship for the various postdevelopment flow types are indicated by the solid lines as compared to the estimated predevelopment relationship for all flow types by the dashed line. As seen in Figure VII-11, the primary departure from predevelopment suspended sediment concentration appears to occur during rainfall and "Stage I" snowmelt conditions.

The relative suspended loads for the various postdevelopment flow types are listed in Table VII-6. In most instances, the majority of suspended sediment load to West Martis Creek occurred during snowmelt periods, principally during the heavy spring-melt period. The only apparent exception to this was runoff from the Northstar ski area during water year 1975. The vast majority (79.3 percent) of the suspended sediment load that year came during rainfall periods. A partial explanation is that much of the overland flow from the ski area is percolated and intercepted by a groundwater collection system for water supply purposes. This results in only very intense rainstorms actually producing any measurable overland flow. The water intercepted by the collection system is usually discharged back to West Martis Creek immediately after collection, except as needed for domestic supply. The collected groundwater flow typically has very low suspended sediment concentrations. A graphical presentation of the suspended sediment loads in West Martis

CORRELATION OF SUSPENDED SEDIMENT CONCENTRATION
WITH STREAMFLOW AT GAUGE # 3
WEST MARTIS CREEK (NORTHSTAR)



STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

STREAMFLOW
WEST MARTIS

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER
VII-11

TABLE VII-5

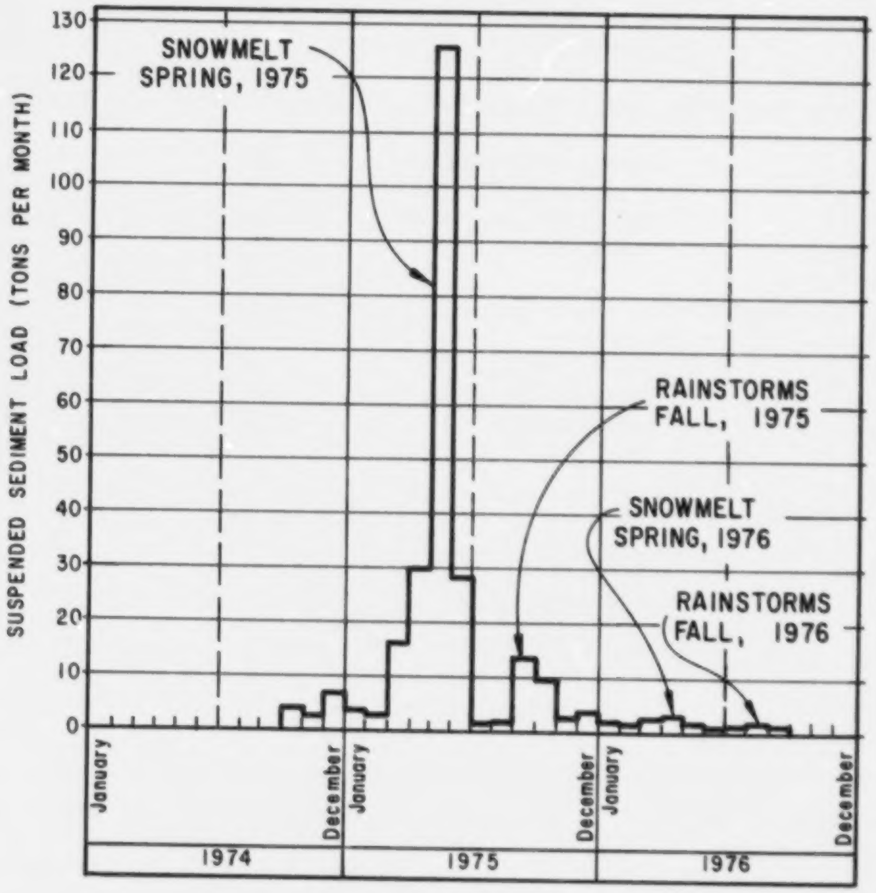
SUSPENDED SEDIMENT CORRELATIONS FOR
WEST MARTIS CREEK

RUNOFF TYPE	CONVERSION*	DATA POINTS	PERCENT SIGNIFICANCE
Gage No. 1. (just below majority of ski area)			
Rainfall	SS=75.9(Q)+151.	7	>99%
All Snowmelt Types	SS=1.82(Q)+1.00	16	>99%
Low Flow	SS=4.18	12	N/A
Gage No. 2. (on East Fork, West Martis Creek, at confluence with West Fork)			
Rainfall	SS=3.49(Q)-49.82	15	>95%
Stage I	SS=2.78(Q)-55.33	27	>99%
Stage II	SS=.326(Q)-4.70	10	>98%
Low Flow	SS=4.01	13	N/A
Gage No. 3. (on West Martis Creek below all development)			
Rainfall	SS=1.14(Q)-68.4	18	>99.9%
Stage I	SS=.397(Q)-34.3	28	>99.9%
Stage II	SS=.078(Q)+1.90	10	>99.9%
Low Flow	SS=7.75	13	N/A
Gage No. 3. (Pre-development)			
All Flow Types	SS=.121(Q)+.085	9	>99%

* Note: SS = Suspended Sediment Concentration (mg/l)
Q = Streamflow (l/sec)

Creek during 1975 and 1976 is presented in Figure VII-12. By comparing this graph to Figure VII-3, it is possible to see how suspended sediment loads do fluctuate with various levels and types of streamflow within West Martis Creek.

Suspended sediment loads at Gage No. 1 are representative of the disturbances within the ski area portion of the development. Gage No. 2 loads are representative of input from the East Fork of West Martis Creek, while Gage No. 3 loads are assumed to represent the total sediment load from the entire upstream watershed. Thus, any increase in sediment load between Gage No. 1 and Gage No. 3, minus the East Fork input, is assumed to be from the heavily developed portions of the Northstar development (condominiums, roadways, Village Center, parking areas, etc.).



SUSPENDED SEDIMENT LOAD IN WEST MARTIS CREEK (NORTHSTAR) ESTMATED BY WATER QUALITY MODEL FROM OCTOBER, 1974 THROUGH SEPTEMBER, 1976

STATE OF CALIFORNIA
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SEDIMENT LOAD
WEST MARTIS

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER VII-12

TABLE VII-6

POST-DEVELOPMENT SUSPENDED SEDIMENT CONTRIBUTION TO WEST MARTIS CREEK (NORTHSTAR) FOR VARIOUS FLOW TYPES

FLOW TYPE	% OF TIME	SUSPENDED SEDIMENT LOAD (METRIC TONS)					
		GAGE #1	%	GAGE #2	%	GAGE #3	%
- - WATER YEAR 1975 - -							
Low Flow	39	0.08	0.1	0.58	3.2	8.46	3.6
Rainfall	5	47.54	79.3	5.35	29.5	48.66	20.6
Snowmelt	56	12.34	20.6	12.21	67.3	179.30	75.8
Total	100	59.96	100.0	18.14	100.0	236.42	100.0
- - WATER YEAR 1976 - -							
Low Flow	46	0.03	15.8	0.65	4.2	3.29	11.8
Rainfall	4	0.05	26.3	3.03	19.7	11.76	42.1
Snowmelt	50	0.11	57.9	11.72	76.1	12.89	46.1
Total	100	0.19	100.0	15.40	100.0	27.94	100.0

Table VII-7 is a summarization of the suspended sediment load per unit area from the various portions of Northstar as calculated in this manner. The postdevelopment loads are compared with the estimated predevelopment suspended sediment load from the entire watershed. Lacking any significant detailed information on tributary predevelopment loads, the total predevelopment suspended sediment load was estimated for the postdevelopment years for which streamflow records existed. Had the Northstar development not occurred, the unit suspended sediment load would have been an estimated 12.34 metric tons per square kilometer compared to an actual 24.12 metric tons per square kilometer for water year 1975. For water year 1976, a much drier year than 1975, suspended sediment load would have been an estimated 1.47 metric tons per square kilometer compared to an actual 2.85 metric tons per square kilometer. Thus the overall postdevelopment loads are estimated to have increased almost 100 percent due to the construction of Northstar. For water year 1975, unit

TABLE VII-7

SUSPENDED SEDIMENT LOADS TO WEST MARTIS CREEK
AS DEVELOPED BY WATER QUALITY MODEL

SOURCE	SUSPENDED SEDIMENT LOAD (METRIC/TONS)	TRIBUTARY AREA (KILOMETERS^2)	UNIT LOAD (METRIC TONS/KM^2) YEAR	PERCENT INCREASE ABOVE BACKGROUND
- - WATER YEAR 1975 - -				
Ski Area	59.96	2.94	20.39	65 %
Development	156.82	5.43	28.88	134 %
East Fork	19.62	1.43	13.72	11 %
Total W. Martis	236.40	9.80A/	24.12	95 %
ESTIMATED PREDEVELOPMENT CONDITIONS FOR WATER YEAR 1975				
Total W. Martis	161.43	13.08B/	12.34	--
- - WATER YEAR 1976 - -				
Ski Area	.642	2.94	0.22	-85 %
Development	11.89	5.43	2.19	49 %
East Fork	15.40	1.43	10.77	630 %
Total W. Martis	27.93	9.80A/	2.85	94 %
ESTIMATED PREDEVELOPMENT CONDITIONS FOR WATER YEAR 1976				
Total W. Martis	19.29	13.08B/	1.47	--

A/ Total area above Gage No. 3 minus area above storage reservoir
B/ Total area above Gage No. 3 including area above storage reservoir

suspended sediment loads for the heavily developed portion of the West Martis Creek watershed are estimated to be increased 134 percent above predevelopment levels. The majority of this increase comes from disturbed slopes, unrevegetated areas, concentrated runoff, and winter road sanding operations associated with the development. Nonetheless, it must be realized that the suspended sediment increase in West Martis Creek due to development within the watershed has not been excessive.

As was mentioned in the section discussing benthic macroinvertebrates, this doubling of suspended sediment load has apparently had minimal impact on aquatic life in the stream. It is likely that those areas that are producing higher than background levels of sediment yield may be controlled in the future by application of additional erosion and sediment control technology.

LONELY GULCH CREEK

The basic equations correlating suspended sediment concentration (SS-mg/l) with streamflow (Q-l/sec) for the two streamflow gages on Lonely Gulch Creek are listed in Table VII-8. Gage No. 5 monitored streamflow in Lonely Gulch Creek above Rubicon Properties Subdivision, while Gage No. 6 monitored streamflow below the development. The suspended sediment versus flow relationship for Gage No. 5 has been corrected for any settling that might occur in the small reservoir just above Gage No. 5. Samples collected above the reservoir usually had 10 percent greater suspended sediment concentration than did samples collected just below the reservoir. The significance levels computed for the correlated suspended sediment versus flow relationships are less than those developed to represent conditions in West Martis Creek. Any relationship between runoff, erosion, and sediment transport in Lonely Gulch Creek is complicated by: (1) the comparatively small size of the watershed, (2) the extremely high levels of concentrated erosion, (3) the erratic deposition and resuspension of large sediment particles depending on the local stream gradient and instantaneous flow rate, and (4) the loss of streamflow as percolating groundwater in the lowest portions of the watershed. Although the correlation of low flow suspended sediment levels at Gage No. 6 is extremely poor (77.2 percent), the significance of low flow conditions in comparison to rainfall and snowmelt contribution is minor. Similarly, even though the significance levels of rainfall and snowmelt (94.5 percent

TABLE VII-8

SUSPENDED SEDIMENT CORRELATIONS FOR LONELY CREEK GULCH

RUNOFF TIME	CONVERSION*	DATA POINTS	PERCENT SIGNIFICANCE
Gage No. 5 (above all development)			
All Flow Types	SS=.043(Q)+0.85	70	>99.9 %
Gage No. 6 (below all development)			
Rainfall	SS=38.1(Q)-656.	7	>94.5 %
All Snowmelt	SS=.853(Q)-14.5	36	>92.5 %
Low Flow	SS=.024(Q)-1.29	24	>77.2 %

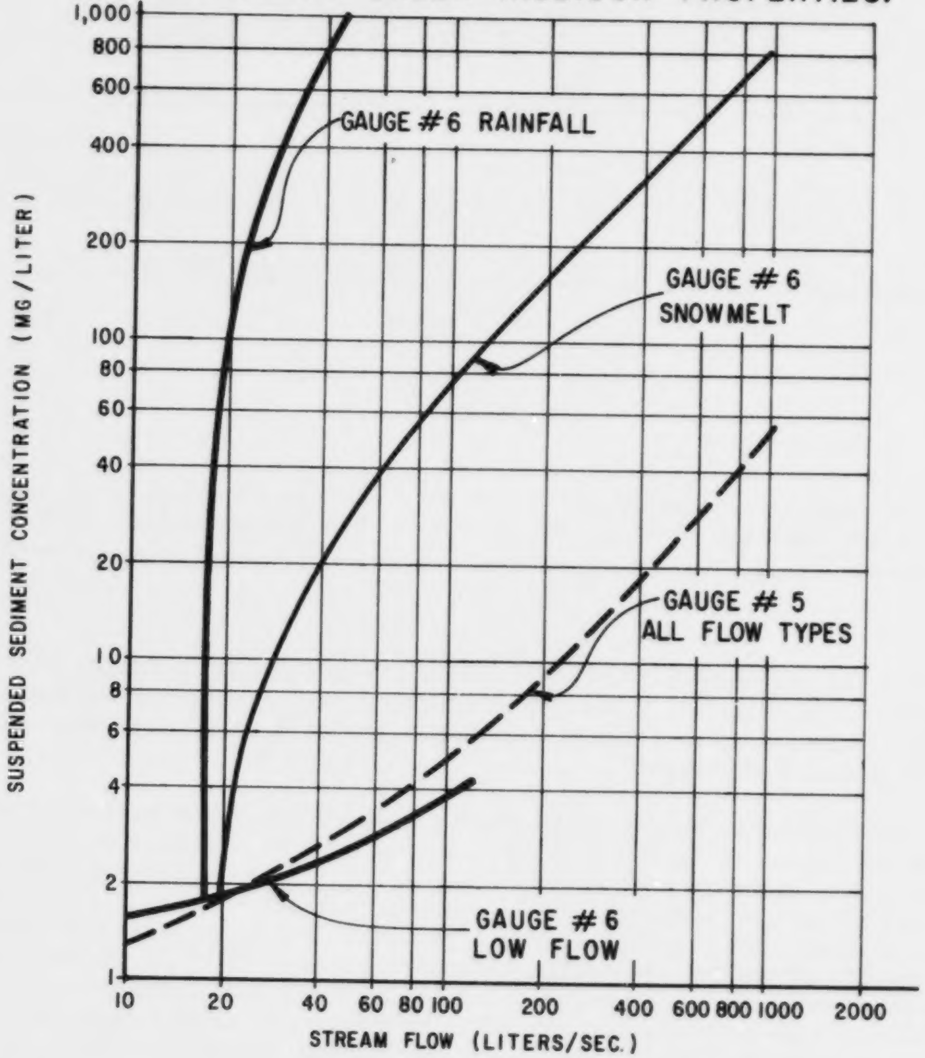
* Note: SS = Suspended Sediment Concentration (mg/l)
Q = Streamflow (l/sec)

and 92.5 percent) are slightly lower the 95 percent limit usually considered acceptable, their relationships are felt to be reasonable estimates of expected suspended sediment levels in Lonely Gulch Creek.

Unfortunately, there is a complete lack of information on the level of suspended sediment and erosion rates in the Lonely Gulch Creek system prior to development. This problem was circumvented by assuming that sediment yield per unit area monitored at Gage No. 5, above the entire development, would be considered representative of predevelopment conditions for the entire watershed.

A graphical presentation of the suspended sediment concentration versus streamflow relations at Gage No. 5 and Gage No. 6 is shown in Figure VII-13. The below-development relationships are depicted by solid lines,

CORRELATION OF SUSPENDED SEDIMENT CONCENTRATION WITH STREAMFLOW AT GAUGES #5 & #6 LONELY GULCH CREEK (RUBICON PROPERTIES)



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STREAMFLOW
LONELY GULCH

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER
VII-13

TABLE VII-9

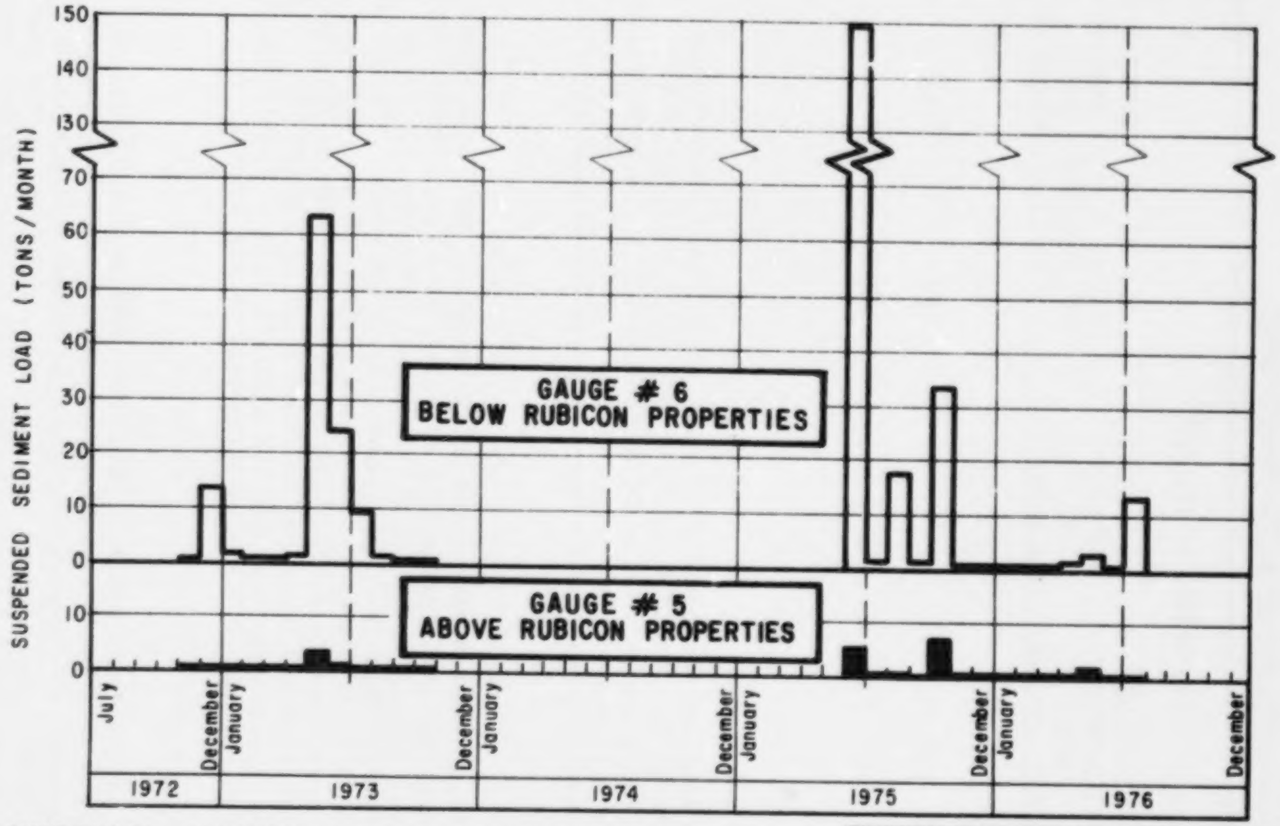
SUSPENDED SEDIMENT CONTRIBUTION TO LONELY GULCH CREEK (RUBICON) FOR VARIOUS FLOW TYPES

FLOW TYPE	% OF TIME	SUSPENDED SEDIMENT LOAD (METRIC TONS) FOR TOTAL PERIOD OF RECORD A/ GAGE #5	%	GAGE #6	%
Low Flow	43	3.37	16.8	1.61	0.5
Rainfall	3	5.26	26.4	119.29	36.0
Snowmelt	54	11.33	56.8	210.53	63.5
		19.96	100.0	331.43	100.0

A/ Period of record includes 27 months of data at Gage #5 and Gage #6 from November 1973 through October 1974 and June 1975 through August 1976

whereas the above-development relationship is shown by a dashed line. A substantial jump in rainfall and snowmelt runoff suspended sediment concentrations occurs between Gage No. 5 (above development) and Gage No. 6 (below development).

The relative contribution of suspended sediment load for various flow types is presented in Table VII-9. As was true of the West Martis Creek system, the majority of the suspended sediment load is contributed during the winter months and peak spring snowmelt period. The most intense conbribution occurs during rainfall periods. Although only 3 percent of the period of record was during rainstorm events, fully 36 percent of suspended load monitored below the Rubicon Properties development occurred at these times. A graphical presentation of the suspended sediment loads in Lonely Gulch Creek during the period of record is presented in Figure VII-14. By comparing this graph to Figure VII-6, it is possible to see how suspended sediment loads are related to, and fluctuate with, various levels and types of streamflow within Lonely Gulch Creek. Figure VII-14 demonstrates the vast increase in sediment load between Gages No. 5 and 6.



SUSPENDED SEDIMENT LOAD IN LONELY GULCH CREEK AT GAUGE # 5 (Above Development) AND GAUGE # 6 (Below Development) AS ESTIMATED BY WATER QUALITY MODEL FROM NOV. 1972 - NOV. 1973 & FROM JUNE, 1975 - SEPT. 1976.

STATE OF CALIFORNIA
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SEDIMENT LOAD
LONELY GULCH CREEK

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER
VII-14

TABLE VII-10

SUSPENDED SEDIMENT LOADS TO LONELY GULCH CREEK AS DEVELOPED BY WATER QUALITY MODEL

- - TOTAL PERIOD OF RECORD[A/] - -

SOURCE	SUSPENDED SEDIMENT LOAD (METRIC TONS/YR)	TRIBUTARY AREA ($KILOMETER^2$)	UNIT LOAD (METRIC TONS/KM^2) (YEAR)	PERCENT INCREASE ABOVE BACKGROUND
Upper Watershed	8.129	2.37	3.43	0 %[B/]
Development	138.228	0.38	366	10,600 %
Total Watershed	147.357	2.75	53.6	1,460 %

[A/] Period of record includes 27 months or data at Gage #5 and Gage #6 from November 1973 through October 1974 and June 1975 through August 1976

[B/] Upper watershed values are assumed to be representative of background levels for entire watershed

A further comparison between background and development suspended sediment yield conditions within the Lonely Gulch Creek watershed is given in Table VII-10. As shown, the suspended sediment load per unit area increases from 3.43 ton/km^2/year from the upper watershed to 366 ton/km^2/year from the Rubicon Properties development. This is a 10,600 percent increase. The total yield from the entire watershed is increased 1,460 percent to 53.6 tons/km^2/year. As was indicated by the results of the benthic macroinvertebrate monitoring, this massive sediment load to Lonely Gulch Creek has had a severe impact on the aquatic life of the stream.

F. SUMMARY AND CONCLUSIONS

One of the most significant results of the suspended sediment sampling program at Northstar was that it enabled the project staff to determine the location and relative severity of erosion problems remaining after initial construction. Clearly, the land disturbance created in the construction of Northstar was held to a minimum. Due to conscientious planning, development, and construction practices, only scattered instances of detectable erosion problems still remain. They are discussed in Section V of this report and are listed as follows:

Problem 1. Oversteepened and unrevegetated slopes adjacent to parking lots and roadways. This problem was mainly located near the wastewater treatment plant, Northstar Drive, and the Village Center. Eroded sediments from these locations discharge to West Martis Creek just above and below its confluence with the East Fork. A substantial effort was made by the project staff to control erosion from these sources (see Appendix B). The total oversteepened, unrevegetated slope area was less than 0.5 hectare.

Problem 2. Urban runoff from the Village Center commercial area. A large portion of the suspended sediment came from sources mentioned in Problem 1 above. Nonetheless, a portion derived from dirt loosened from vehicular traffic in the Village Center area and from winter road sanding operations.

Problem 3. Uncontrolled drainage flowing over an artificially filled and unrevegetated ski run. The areal extent of this problem was about 0.6 hectare near the Village Center. This problem was further compounded by disturbance caused by skiers and maintenance vehicles in the late spring when little snow cover remained.

Problem 4. Heavily traveled dirt road adjacent to and crossing the East Fork of West Martis Creek. The problem here was greatest during spring snowmelt when continuous vehicular traffic would loosen the roadbed, allowing it to be washed into the creek.

Problem 5. Remaining uncontrolled drainage and unrevegetated areas located near the base of the main ski bowl.

Clearly Problems 1 and 2 were the most significant and the most difficult to control, although occasional higher suspended sediment concentrations were recorded elsewhere.

Urban runoff, combined with drainage from oversteepened and unrevegetated slopes near the Village Center, was the most frequent and readily discernible source of sediment discharges to West Martis Creek. A large part of the problem was due to a lack of adequate sediment retention facilities for drainage from the Village Center commercial area. A planning recommendation made prior to the construction of Northstar's Village Center anticipated that sediment retention facilities would be required to meet water quality standards. However, such a sediment catchment facility was not provided when the Village Center and its drainage appurtenances were constructed. Although such a catchment devise was not added as part of this demonstration project, addition of such a structure in the future, coupled with careful maintenance, would substantially lower the sediment yield from the Village Center.

It must be emphasized, however, that although the construction and development of Northstar has led to a 100 percent increase in the amount of sediment yield, the impact on aquatic life in West Martis Creek has been negligible. Although sampling stations for Benthic macroinvertebrates were established to monitor areas in the Northstar development where siltation and erosion problems were suspected to occur, the macrobenthic community suffered only minor perturbations. The majority of the remaining sediment transport and erosion problems within the West Martis Creek watershed can be further reduced by further revegetation and adequate drainage control. As part of the erosion control project, considerable emphasis was placed on revegetation of disturbed areas and some minor drainage control (see Appendix B). By implementation of these measures, it is believed that suspended sediment transport from the the Northstar development has been further reduced.

Within the Lonely Gulch Creek watershed, on the other hand, it was impossible to determine the relative significance of a number of different sediment discharges from Rubicon Properties Subdivision. All discharges from culverts, ditches, and drainage swales had extremely high levels of transported sediments. While sediment discharge per unit area of watershed above the development was estimated at 3.43 tons/sq km/year, the average estimated discharge from the development was estimated to be 366 tons/sq km/year. This represents a 10,600 percent increase above estimated natural background levels. A graphical comparison of predevelopment and postdevelopment suspended sediment yields at the Northstar and Rubicon Properties erosion control project sites is depicted in Figure VII-15. The difference is not only in suspended sediment yield, but also the differing impact of suspended sediment discharge between Northstar and Rubicon Properties is readily apparent. An almost one-fold increase in sediment yield within the West Martis watershed after development had negligible impact on the monitored benthic macroinvertebrates. Within Lonely Gulch Creek, however, total numbers of macroinvertebrate individuals were reduced to as low as 1 percent of the density found upstream of suspended sediment discharges. The average density of individuals downstream of discharges to Lonely Gulch Creek during 1975 and 1976 was 32 percent of that found upstream. Numbers of different families and diversities of the macroinvertebrate populations were also substantially decreased. Average diversity, a measure of the overall "health" of an ecologic system, was lowered from 2.28 at an upstream station to 1.80 for downstream stations heavily affected by suspended sediment scour and deposition.

While the development of Northstar-At-Tahoe has had a minimal and perhaps acceptable impact upon West Martis Creek, the development of Rubicon Properties has led to the totally unacceptable destruction of Lonely Gulch Creek.

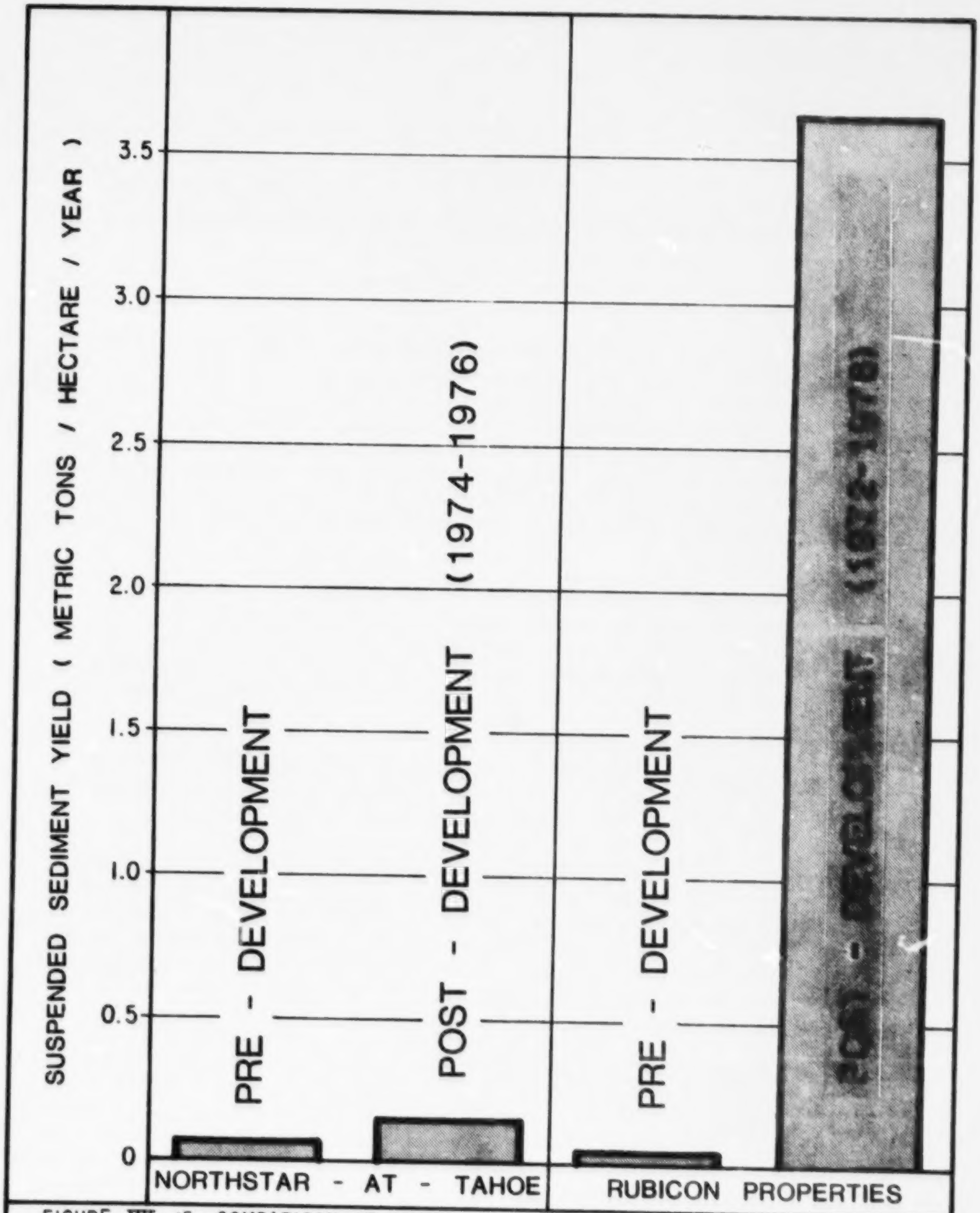


FIGURE VII-15. COMPARISON OF PREDEVELOPMENT AND POSTDEVELOPMENT SUSPENDED SEDIMENT YIELDS AT NORTHSTAR AND RUBICON PROPERTIES PROJECT SITES.

SECTION VIII

BEST MANAGEMENT PRACTICES FOR EFFECTIVE EROSION CONTROL

A. Introduction

A primary objective of this report is to provide timely information on the cost-effectiveness of erosion control methods which could be applied to erosion problems typically found in the Tahoe-Sierra region of California. Because of time, funding, and site limitations, the California State Water Resources Control Board (State Board) was unable to demonstrate all erosion control techniques that might conceivably be used in the environment of the Tahoe-Sierra. With these limitations in mind, the project staff chose to implement and demonstrate those methods which:

- appeared to be the most cost-effective,
- appeared to be environmentally sound,
- the project staff could utilize to develop reliable cost-effectiveness data which otherwise would not be available,
- emphasized source control, rather than treatment after the fact,
- emphasized revegetation, and
- could be easily implemented using unskilled labor, or, if skilled workers and special equipment are required, could be implemented with a low unit cost.

In addition to the above criteria the erosion control project staff placed the most emphasis on those techniques which could be applied to very steep (2:1 or greater) cut and fill slopes (see Figure VIII-1). Very steep slopes are common throughout the Tahoe-Sierra region where extensive past construction activities have been relatively unregulated. Not only do they represent the greatest erosion problem and source of waste sediments transported to the streams and lakes of the region, but they are also the most expensive and difficult problems to control. In addition, those techniques which are applicable to very difficult steep slopes are generally appropriate methods for controlling erosion problems on less severe sites. Several other documents published by the Environmental Protection Agency (41, 42, 43, 44) provide a general, and in some cases quite specific, discussion of the broad spectrum of erosion and sediment control technology currently available. These documents should be consulted for further information on techniques not covered by this project or not included in this report. No attempt has been made to reproduce information which is adequately discussed elsewhere.

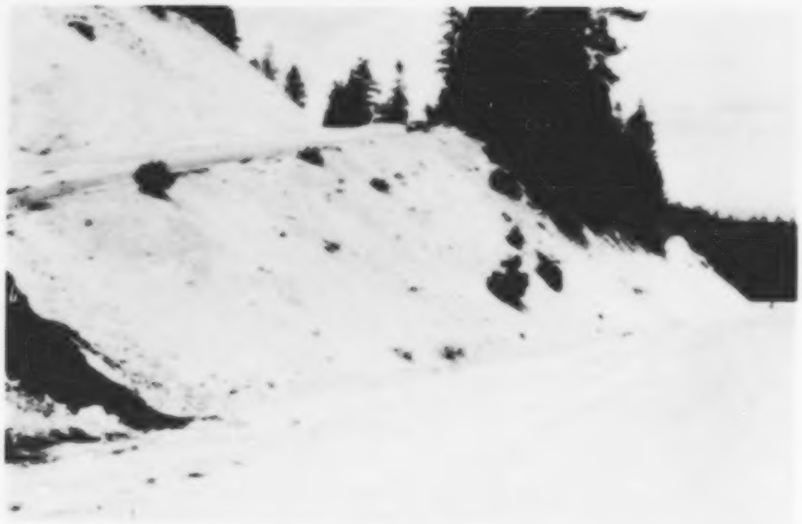


Figure VIII-1. Steeply eroding cut slope adjacent to paved roadway at the Rubicon Properties erosion control project site.

The erosion control methods discussed in this report are subdivided into the following categories.

1. Temporary Siltation Control - Includes filter berms, filter fences, straw bale sediment barriers and impervious berms. These methods are used for temporarily controlling siltation from on-going construction activities and short-lived disturbances (less than 1/2 year). It is fully anticipated when using temporary siltation control methods that they will be replaced by other permanent methods within 1/2 year.

2. Drainage Control - Includes berms, dikes and gutters, drop inlets, rock lined channels, water bars, diversion dikes, percolation trenches and sediment retention basins. These methods are used to control storm drainage and prevent overland flow from eroding disturbed soil surfaces or other highly erodible areas.

3. Mechanical Stabilization of Oversteepened Slopes - Includes curbs, dikes, benches, breast walls, retaining structures, slope scaling, overhang removal, and contour wattling. These methods are used to prepare and stabilize oversteepened slopes to a degree sufficient for the establishment of vegetation.

4. Permanent Vegetative Erosion Control - Includes willow staking, seeding, planting, mulching, fertilization, and irrigation. These methods are viewed as the most appropriate means of stabilizing disturbed areas. If used alone, vegetative erosion control methods

can be expected to achieve a considerable degree of success on less severe slopes (less than 2:1) where drainage control is not a problem. However, on steeper slopes (greater than 2:1) or areas with drainage problems, permanent vegetative erosion control methods must be combined with drainage control and mechanical stabilization techniques.

B. Cost Estimating Procedures

The equivalent costs of erosion control methods used as part of the Erosion Control Demonstration Project are developed from actual material, equipment and labor requirements at the project sites, except when otherwise noted. The following assumptions were used in developing the equivalent cost estimates presented herein, and are presumed to be representative of conditions found in the Tahoe-Sierra region of California.

1. Adverse climatic conditions, such as storms or high winds, are considered not to cause hindrances or delays in the installation of the erosion control methods.

2. Except as otherwise specifically noted, wages and equipment costs are based upon data published by CalTrans (45) as of June 30, 1976, plus an additional 10 percent allowance for profit.

3. Except as otherwise specifically noted, total labor costs are assumed to be $16.25 per hour, including wage (10.75/hr), social security (6%), workmen's compensation insurance (10%), unemployment insurance (5%), and an additional 25 percent to cover overhead, supervision and profit. For comparative purposes, labor costs including overhead and supervision, for county workers and unskilled conservation corps workers are assumed to be $10.00/hr and $5.00/hr, respectively. Much of the erosion control work described herein is very labor intensive. Where possible, for each erosion control method, the percentage of the total cost attributable to labor costs at $16.25 per hour is identified. If different unit labor costs are expected, overall cost estimates should be revised accordingly.

4. All mulching and seeding techniques requiring hydromulching or straw blowing equipment are assumed to be conducted by competitive commercial enterprises. Labor and equipment costs for hydromulching and machine straw mulching are derived from CalTrans "mulch-in-place" contract figures for the first half of 1976. It is assumed that the CalTrans contract amounts include direct and indirect labor and equipment costs, insurance, overhead, supervision, and profit. Materials costs are considered separately.

5. Except as otherwise specifically noted, all materials costs are equivalent to retail costs quoted by the various manufacturers, distributers or suppliers of materials used at the project sites

including estimated shipping costs as of June 30, 1976. Storage costs are not included.

6. Except as otherwise specifically noted, the person-hours assumed to be required to complete a particular task are based upon the observed county and conservation corps person-hours required to perform the task at the Erosion Control Project demonstration sites. Although erosion control labor costs are based upon commercial wage scales, no allowance for increased work efficiency has been included in the cost analysis. This was justified because, in several instances, observed installation times using county personnel and unskilled workers were less than or equivalent to manufacturers estimates or estimates by others based upon the use of skilled or semi-skilled labor. In one case a gabion manufacturer estimated that labor requirements for gabion installation varied from 2.0 to 2.6 person-hours per cubic meter of gabions filled. Experience at the project sites indicated that gabion installation required about 2.17 person-hours per cubic meter of gabions filled. In another case, a report (46) describing willow wattling installation and cost indicated that a semi-professional 7-man crew could install wattling at about 2.70 meters per hour. Unskilled workers at the erosion control project site were able to install wattling at a site of about 3 meters per hour. Thus, using these two cases as indicators of work crew efficiency it is assumed that, for the type of work involved, there are not significant differences in efficiency between unskilled and skilled landscape laborers.

7. The equipment-hours, other than for hydromulching and straw blowing, are based upon the needs of a 5-person work crew assigned to a particular erosion control task.

8. As a basis for cost estimates, the minimum land area requiring erosion control work is considered to be one hectare. It is assumed that this is a large enough area to attract substantial competitive bidding for a contract to perform the erosion control tasks. Labor and equipment transportation, start up, and shut down costs are considered to be negligible.

9. Maintenance costs are not included; once the initial erosion control work has been completed, such costs are considered to be nominal.

10. Design costs are not included in these cost estimates.

C. Temporary Sedimentation Control

Methods described in this section are intended only for temporary control of erosion problems, not for long term or permanent erosion control. Situations when temporary sedimentation control methods are used include:

- on-going construction activities
- emergency situations
- post-construction periods until permanent control methods are firmly established.

Temporary sedimentation control does not necessarily prevent localized erosion. Its basic purpose in and around the Lake Tahoe Basin is to prevent erodible materials from being transported to surface waters. The Regional Water Quality Control Board requires that eroded earthen materials must be contained within the construction site or property boundaries. Measures must be taken to prevent off-site transport by vehicles, wind and water.

1. Control of Sediment Transport Directly Due to Vehicular Traffic - The main concern is with the transport of earthen material off of the property by construction vehicles. Control measures include:

   a. Well defined access drives to the project, limited to as few as possible.

   b. A clean base material, such as granitic gravel, on all access drives. Volcanic "cinders" are not considered to be "clean", since they have a large percentage of fine particles, and larger particles tend to break down when subjected to loads. Cinders should not be used in any application where there are no down-gradient sedimentation control facilities.

   c. Equipment having a significant amount of mud, etc. attached to it should be washed before leaving the property.

2. Control of Sediment Transport Due to Wind - Limiting the area of soil disturbance as much as possible by holding equipment operating areas to a minimum is the best preventative measure. Other measures include wetting problem surfaces or covering them with plastic sheeting, gravel, mulch, fiber netting, asphalt emulsion, or plastic emulsion.

3. Control of Sediment Transport Due to Water Flow - Water flow stemming directly from human activities such as washing, surface wetting and irrigation, can and should be limited. Special measures must be employed to control storm and snowmelt runoff and thereby prevent sediment transport.

The Lake Tahoe Basin and vicinity is subject to heavy snowfall during the winter months, and, in most cases, extensive construction activities during this period are not practical. Furthermore, local regulatory agencies do not allow earth disturbing activities between October 15 and May 1 of the following year and require that all projects be "winterized" by October 15 of each year. "Winterization" means complete installation of all necessary temporary and/or permanent erosion and sediment control facilities.

Ideally, temporary sedimentation control facilities should be designed to withstand tributary runoff flows due to a storm of a given recurrence interval. For design purposes, the Regional Water Quality Control Board (Regional Board) uses a 20-year, 1-hour storm as the critical design storm. The Regional Board recommends use of the SCS triangular hydrograph method for determining tributary runoff from a specific site during the design storm. This method is further discussed under infiltration trench design.

1. Impermeable Berm

An impermeable berm is generally constructed by forming an earthen dike, covering the dike with impermeable plastic sheeting, and placing clean gravel on the lower edges of the plastic as shown in Figure VIII-2 (see Section A-A), or burying the edges to a depth of about 10 centimeters. A "storage dike" (see Figure VIII-2, Case A) should be positioned at the down gradient end of the disturbed soils area such that all flows from the project site are retained by it. Diversion dikes, as shown below point "C", may be necessary. The storage should be extended uphill a distance 'L' as identified in Figure VIII-2, Case A, to maximize storage capacity.

The height of the down-gradient perimeter of the storage dike should be based on storage requirements determined by an estimation of maximum runoff flow to the berm in a 20-year, 1-hour design storm. To decrease runoff to the storage dike, a diversion dike may be used to divert runoff above a disturbed area (Figure VIII-2, Case B). Care must be taken in the design and placement of diversion facilities to prevent erosion on adjacent areas due to channelization of flow and discharge. Figure VIII-3 depicts a typical impervious berm installation.

As a minimum, the following design criteria should be included in specifications for the construction of impervious berms:

a. the berm shall be constructed of available earthen material mounded to a height of at least .33 meter,

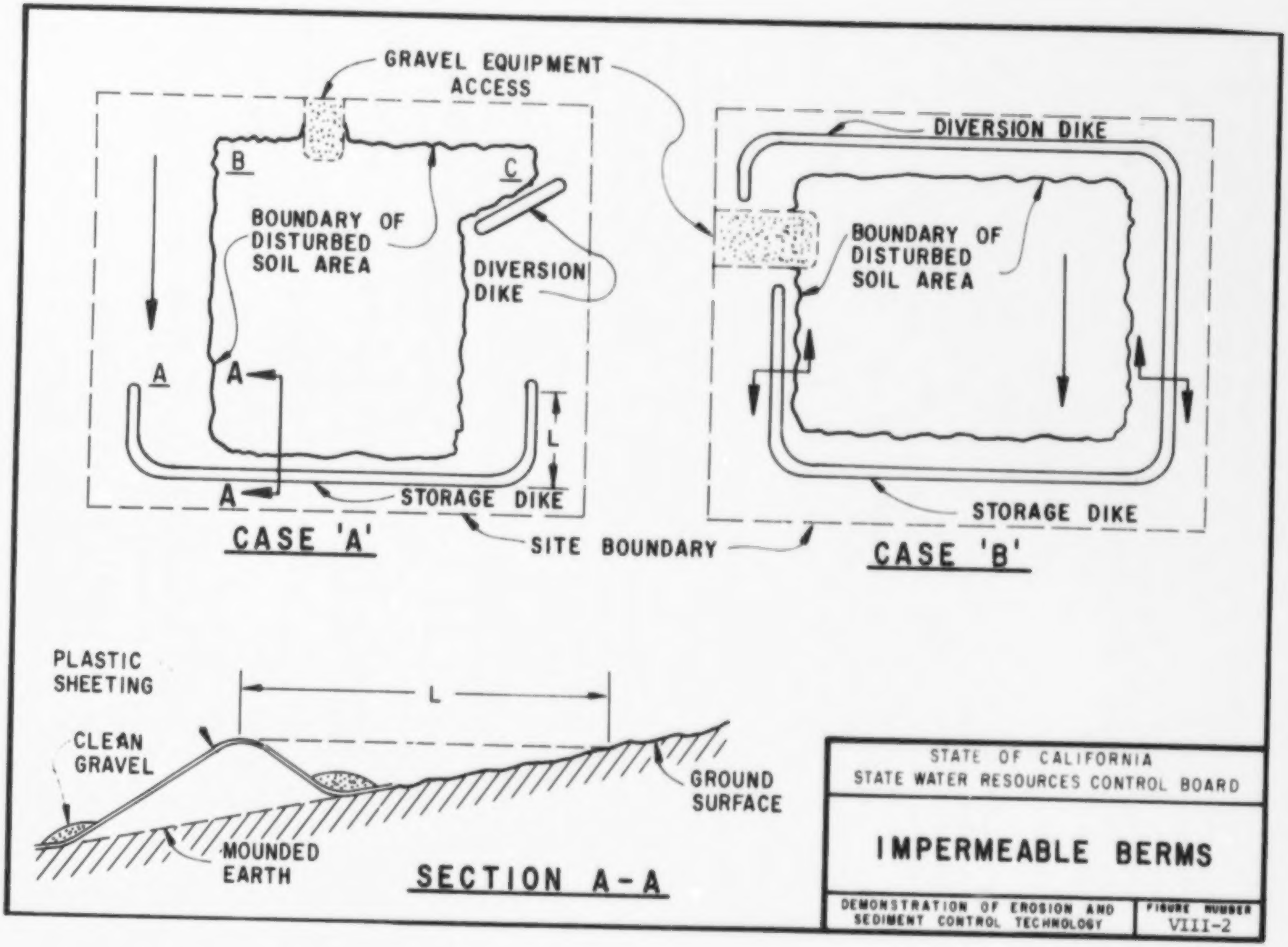
b. the sides of the berm shall be laid back to a slope of no greater than 1.5:1,

c. the surface of the berm shall be free of rocks or protrusions,

d. translucent plastic sheeting with a thickness not less than 6 mil shall be placed over the earthen berm,

e. the outside edges of the plastic sheeting shall be covered with clean gravel or buried to a depth of 10 centimeters,

f. the dike shall be frequently inspected and repaired if necessary, and


GRAVEL EQUIPMENT ACCESS
B
C
BOUNDARY OF DISTURBED SOIL AREA
DIVERSION DIKE
A
A
A
L
STORAGE DIKE
CASE 'A'
SITE BOUNDARY
DIVERSION DIKE
BOUNDARY OF DISTURBED SOIL AREA
STORAGE DIKE
CASE 'B'
PLASTIC SHEETING
L
CLEAN GRAVEL
GROUND SURFACE
MOUNDED EARTH
SECTION A-A

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

IMPERMEABLE BERMS

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER VIII-2

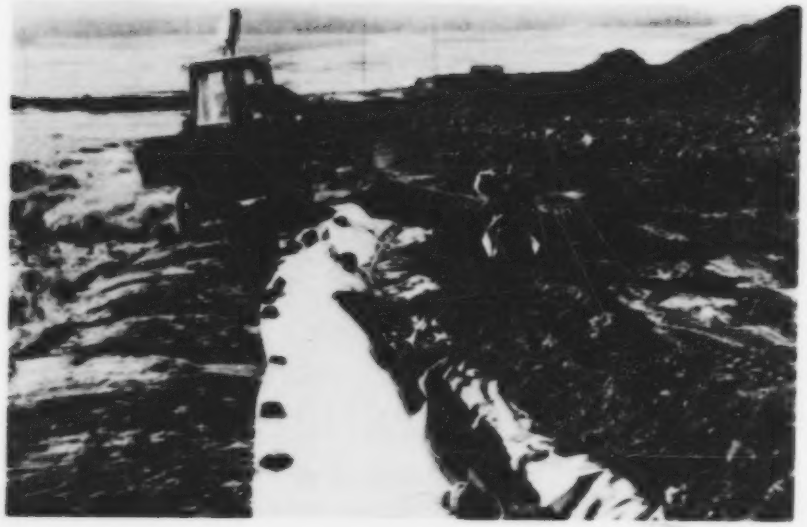


Figure VIII-3. Impervious berm installation adjacent to a stream channel at the Northstar erosion control project site.

g. the impervious berm shall be removed once permanent erosion and drainage control measures have been completed and are established.

2. Straw Bale Sediment Barriers

A straw bale sediment barrier is generally constructed by laying bound straw bales to form a wall or barrier. The function of a straw bale sediment barrier differs from an impervious berm in that it is designed to pass water while filtering and blocking transported sediments. Straw bale sediment barriers are useful not only in constructing extensive barriers for the prevention of sediment transport from construction sites but also in preventing transported sediment from being discharged to specific points, such as drop inlets. Figure VIII-4 depicts a typical erosion problem discharging to a drop inlet. Figure VIII-5 depicts a straw bale sediment barrier designed to prevent such a discharge. Once the problem is corrected at its source, the straw bales should be removed. Since straw bales eventually decompose, they should be replaced or removed prior to such an occurrence. Installed straw bale sediment barriers must be inspected frequently to be sure that their structural integrity is maintained and that loose straw is not being washed into drainage systems. When mixed with mud and water, loose straw forms a sticky mass which can easily clog culverts, drop inlets, or other drainage strutures.

An added benefit of straw bale sediment barriers is once construction activities have halted, and permanent erosion control measures are

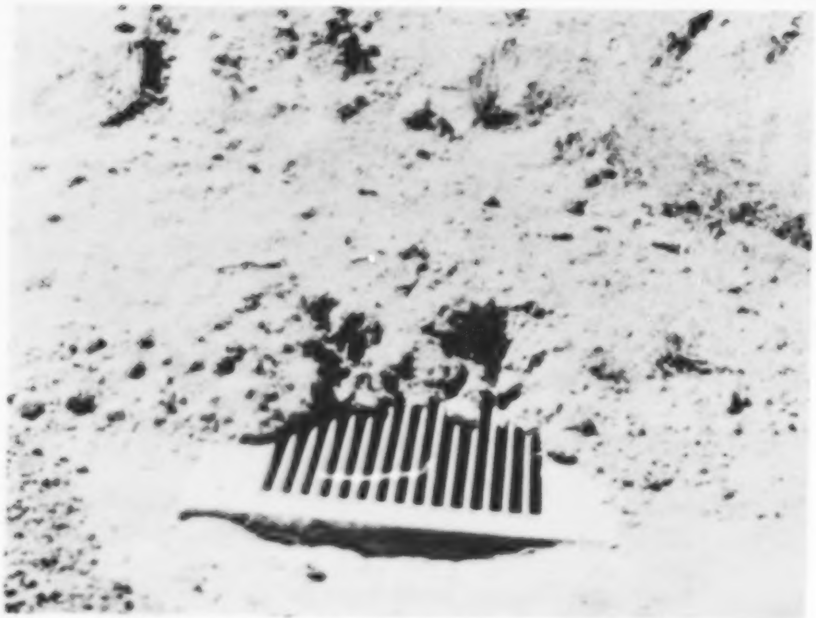


Figure VIII-4. Eroded soil material discharging to drop inlet.

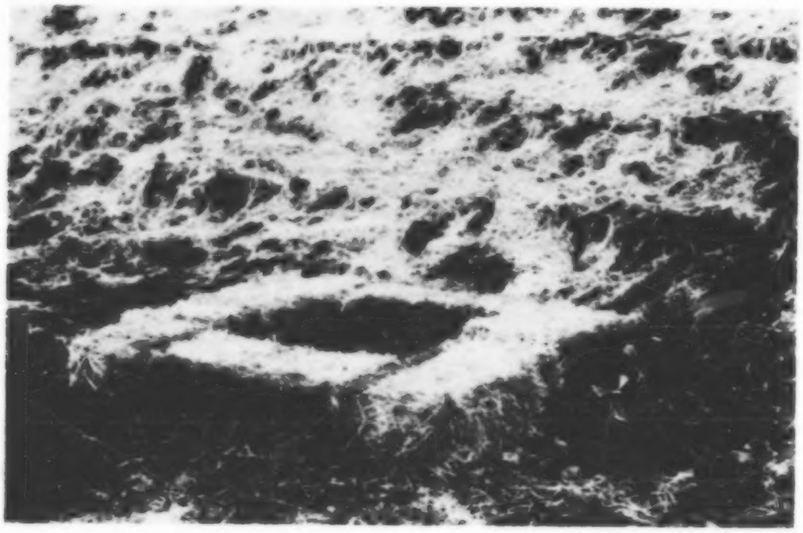


Figure VIII-5. Straw bale sediment barrier used to control problem pictured in Figure VIII-4.

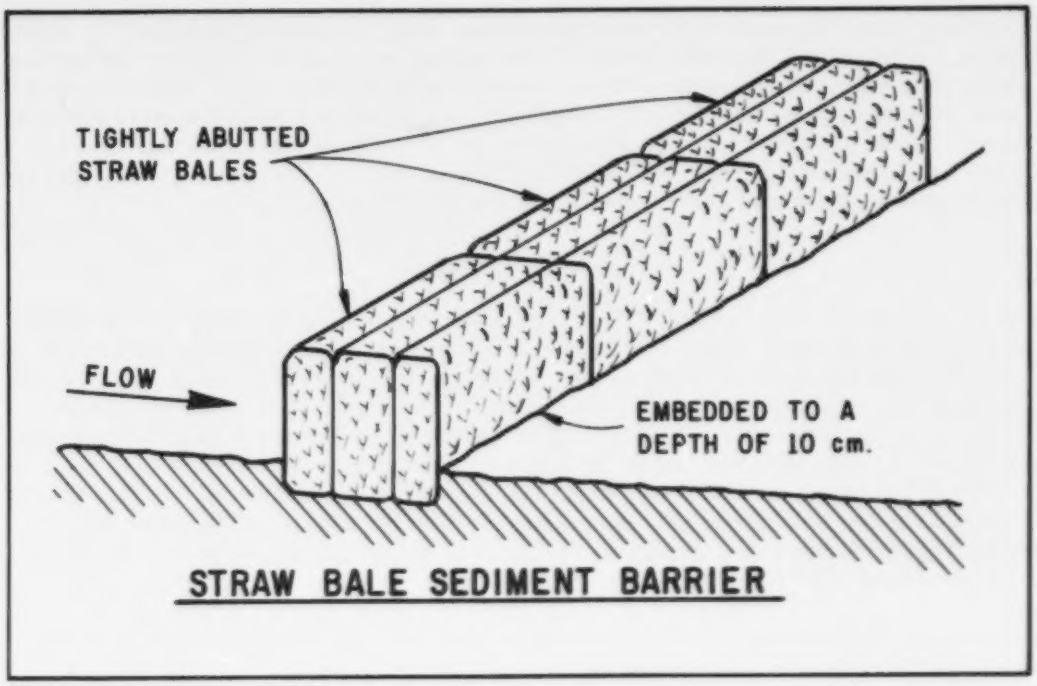

TIGHTLY ABUTTED STRAW BALES
FLOW
EMBEDDED TO A DEPTH OF 10 cm.
STRAW BALE SEDIMENT BARRIER

Figure VIII-6. Typical straw bale sediment barrier installation design.

established the straw bales may be used as a mulch to aid in the establishment of vegetation on the disturbed landscape. Because of the straw bales' exposure to the elements, it is unlikely that the straw could be applied in a mechanical mulching operation. However, the "weathered" straw mulch may still be readily applied by hand.

A typical straw bale sediment barrier installation is depicted in Figure VIII-6. As a minimum, the following design criteria should be included in the specifications for the construction of straw bale sediment barriers:

a. straw bales shall be placed in a row on the contour with ends tightly abutting adjacent bales,

b. each bale shall be embedded in the soil to a minimum depth of 10 centimeters,

c. the straw bale sediment barrier shall be inspected frequently and repaired if necessary, and

d. the straw bales shall be removed once permanent erosion and drainage control measures have been completed and are established.

Surface contact between the straw bales and the ground surface is sometimes a problem, particularly if the bales are insufficiently embedded. Portions of broken bales placed beneath the barrier will assure contact and provide more complete filtration. An optional added specification could also provide for the anchoring of the straw bales by means of re-bar or stakes. Such a specification would be required if the barrier were potentially subject to high flows or other stress.

3. Filter Berms

A filter berm is constructed in the same manner as an impervious berm with the exception that the berm is constructed of material designed to permit the passage of water, and at the same time filtering transported sediments. Filter berms do not require the extensive storage areas required by impervious berms. They eventually become clogged with the sediments they are designed to remove. Frequent inspection and continued maintenance of a filter berm installation is required to insure satisfactory performance. Maintenance may involve simple cleaning of the filter berms, or, in some instances, require complete replacement of sections of the berm.

Adequate filtration by a filter berm is based on proper pore size in the filtration media. For example, gravel filters will not provide adequate filtration of most suspended sediment material. Two typical designs for acceptable filter berms are shown in Figure VIII-7. At a minimum the following design criteria should be included in the specifications.

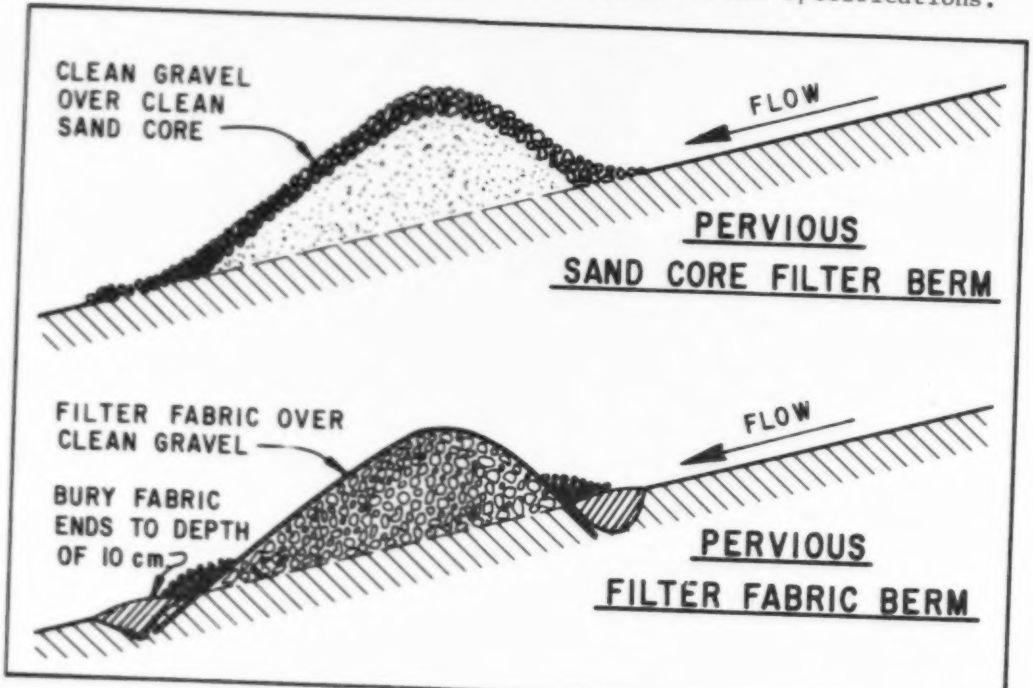

CLEAN GRAVEL OVER CLEAN SAND CORE
FLOW
PERVIOUS SAND CORE FILTER BERM
FILTER FABRIC OVER CLEAN GRAVEL
BURY FABRIC ENDS TO DEPTH OF 10 cm
FLOW
PERVIOUS FILTER FABRIC BERM

Figure VIII-7. Typical pervious filter berm installation designs.

For the construction of a sand core filter berm:

a. the sand core filter berm shall be constructed of coarse clean sand with not more than 5 percent (by weight) of the particles less than .06 mm in diameter,

b. the sand core shall be mounded to a height of not less than 30 centimeters,

c. the sides of the sand core shall be at a slope of not greater than 1.5:1,

d. the sides of the sand core shall be covered with clean gravel to a depth of not less than 10 centimeters, and

e. not more than 5 percent (by weight) of the gravel shall have diameters larger than 5 centimeters, or less than 1 centimeter.

For the construction of a filter fabric berm:

a. the filter fabric berm shall be constructed using a core of clean gravel with not more than 5 percent (by weight) of the gravel having diameters not larger than 5 centimeters, nor less than 1 centimeter,

b. the gravel core shall be mounded to a height of not less than 30 centimeters,

c. the sides of the sand core shall be at a slope of not greater than 1.5:1,

d. the gravel core shall be free of any protrusions,

e. over the gravel core shall be placed filter fabric material,

f. the outer edges of the filter fabric shall be buried at the base of the gravel core to a depth of 10 centimeters, and

g. clean gravel shall be placed to a depth of not less than 10 centimeters along the inside and outside base of the berm.

For both the sand core and filter fabric berms, the following specifications should be included:

- the filter berm shall be inspected frequently and repaired if necessary, and
- the filter berm shall be removed once permanent erosion and drainage control measures have been completed.

4. Filter Fences

Filter fences control controlling siltation in the same manner as filter berms. Filter fences are particularly advantageous where space is limited. Impermeable dikes, straw bale sediment barriers, and filter berms can require up to 2-meter wide strips for their construction. Filter fences, on the other hand, can be placed in less than .5 meter strips around a disturbed site. Figure VIII-8 depicts a typical filter fence installation designed to protect a stream from siltation generated by the construction of an adjacent golf course.

A diagram showing a typical filter fence installation procedure is presented in Figure VIII-9. At a minimum, the following design criteria should be included in the specifications for the construction of filter fences:

a. the fence shall be constructed of cross woven welded wire fence material with openings not greater than 10 cm x 10 cm,

b. the welded wire fencing shall be securely attached to fence posts firmly planted in the ground at spacings not greater than 3 meters,

c. the fence posts shall be located on the down slope side of the fence and extend at least .5 meter above the ground surface,

d. the welded wire fencing shall be tensioned between fence posts,

e. pervious filter fabric shall be placed on the up slope side of the fence with a portion folded over the fence top and with at least .25 meter remaining at the toe which will be buried,

f. the filter fabric shall be attached in such a manner as not to rend or tear the fabric,

g. on the up slope side of the fencing, the foot of the fabric shall be buried to a depth of not less than .25 meter,

h. replaced soil shall be firmly tamped after the filter fabric foot has been placed,

i. all operations involving the construction of the filter fence shall be conducted so as not to tear or otherwise increase the porosity of the filter fabric,

j. once constructed, the filter fence shall be frequently inspected and repaired if necessary, and

k. the filter fence shall be removed once permanent erosion and drainage control measures have been completed.

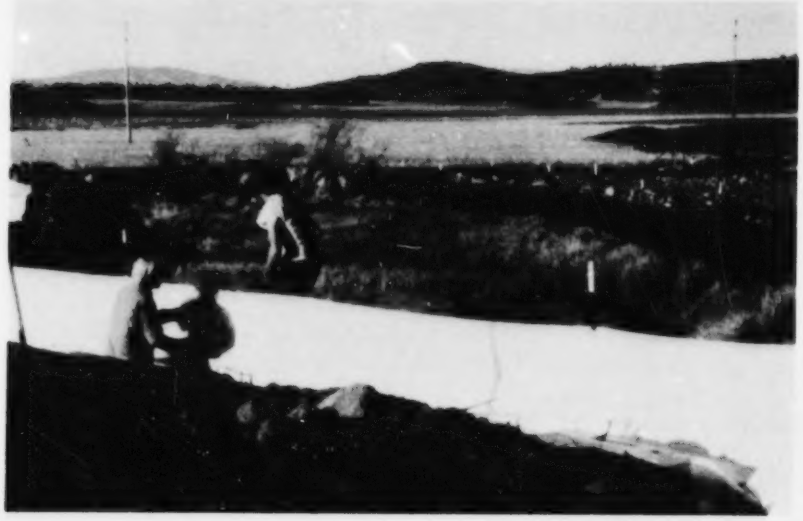


Figure VIII-8. Filter fence installation adjacent to a stream channel at the Northstar erosion control project site.

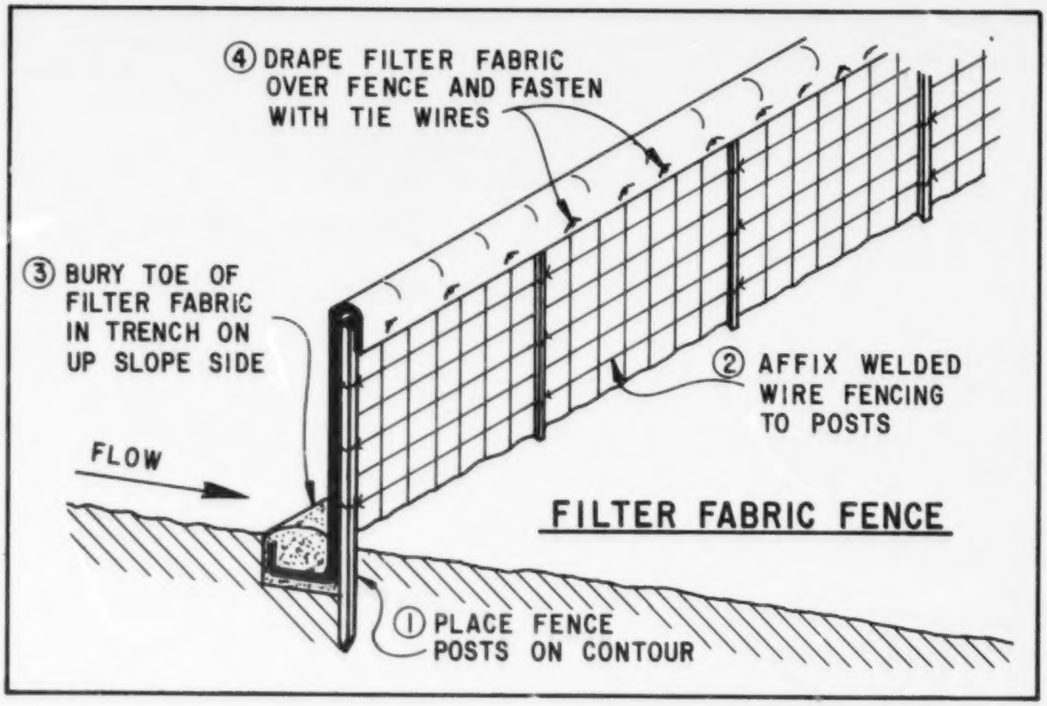

④ DRAPE FILTER FABRIC OVER FENCE AND FASTEN WITH TIE WIRES
③ BURY TOE OF FILTER FABRIC IN TRENCH ON UP SLOPE SIDE
② AFFIX WELDED WIRE FENCING TO POSTS
FLOW
FILTER FABRIC FENCE
① PLACE FENCE POSTS ON CONTOUR

Figure VIII-9. Typical filter fence installation design.

5. Comparative Costs of Temporary Siltation Control Methods

The cost of constructing temporary siltation control facilities may vary widely depending on availability of materials and type of construction sites, including the space available for siltation control facilities.

Table VIII-1 lists the equivalent cost of the various types of siltation control facilities constructed at Northstar erosion control project site. Cost estimates are based on assumptions listed earlier in this section and include one-time installation costs only.

Although the above costs are only estimates, it is possible to say that the filter berms and fences are roughly twice as costly as a simple impervious earthen berm. On the other hand, an impervious berm requires a considerable amount of water storage space behind the berm to effectively settle suspended sediments. The cost of committing such space is not reflected in these estimates.

The straw bale sediment barrier (intermediate expense) has the added advantage that the materials may be reused as mulch. The filter fence also has the advantage that its materials may be reused. These savings are not reflected in the above cost estimates. Although filter fences have received little use in the Tahoe-Sierra area, it does appear that their expense and effectiveness are highly competitive with other temporary sedimentation control devices.

TABLE VIII-1

TEMPORARY SILTATION CONTROL
EQUIVALENT INSTALLATION COSTS

	UNIT COSTS ($/METER)			
	MATERIALS	EQUIPMENT	LABOR	TOTAL
Impervious Earthen Berm (30 cm high)	.30	1.18	1.60	3.08
Straw Bale Sediment Barrier	1.80	----	2.71	4.51
Sand Core Filter Berm (30 cm high)	4.33	1.18	1.60	7.11
Filter Fabric Berm (30 cm high)	4.00	1.18	1.60	6.78
Filter Fabric Fence (50 cm high)	2.00	1.18	3.88	7.06

D. Drainage Control

When considering methods required for the effective control of erosion and sedimentation, adequate control and drainage of storm waters is of primary importance. It makes little sense to commit a large effort to the establishment of permanent erosion control by means of revegetation, if storm waters are allowed to wash everything away. Uncontrolled runoff from impervious surfaces can easily cause significant erosion problems even if the majority of an erosion control project site is adequately revegetated. Not only will uncontrolled storm runoff generate localized erosion in drainage swales and channels on the construction site, but it will also cause further erosion problems elsewhere if allowed to discharge to natural channels and streams which are not large enough to handle excessive storm water flows. These off-site erosion problems will be manifest in the form of increased streambank erosion and channel scouring.

Effective drainage control is based on two principles:

1. all concentrated runoff should be carried in non-erodible ditches and swales,
2. when possible, all storm runoff from impervious surfaces must be infiltrated with no direct discharge to surface waters.

If these two principles are universally applied, in conjunction with effective revegetation of disturbed areas, erosion problems will be significantly reduced, if not eliminated. In all future construction in the Tahoe-Sierra region these two basic tenets must be adhered to.

The application of this drainage control approach to past construction sites may be difficult. In many cases the amount of impervious surface coverage vastly exceeds the capacity of remaining pervious areas to percolate storm runoff. In other instances, there is not sufficient space for the installation of runoff interception works or percolation trenches due to the close proximity of impervious surfaces to stream zones or due to intervening steep or difficult terrain.

The Rubicon Properties erosion control project site is in an area where all these difficulties are encountered. Totally effective drainage control at such a site would be very expensive. In locations such as Rubicon Properties where effective percolation of storm drainage is prohibitively expensive or impossible, the erosion control program must concentrate heavily upon stabilization of disturbed slopes and construction of non-erodible drainage swales. If transport of sediment to surface waters remains a major problem, sediment retention basins would then be required to further reduce the sediment load. A small sediment retention basin can be quite effective in reducing sediment load during storms, but would not be effective as a percolation pond to substantially limit peak storm water flows from impervious surfaces.

This section on drainage control is not intended to be a design handbook for drainage control structures. For the appropriate design and sizing of particular drainage control structures, a registered civil engineer should be consulted. Various publications by the EPA (41, 42, 43) offer details on the design and layout of several drainage control facilities not discussed in this report including: check dams, chutes and flumes, erosion checks, Fabriform® Erosion Control Mats, flexible downdrains, and level spreaders. The project staff did not feel they would be effective within the project sites, or in the surrounding vicinity. Drainage control methods and structures which are mentioned are included because:

- they are fundamental to effective drainage/erosion control,
- they are or have been frequently omitted from projects in the Tahoe-Sierra region of California,
- their effectiveness has been demonstrated or observed within the project sites and/or surrounding vicinity.

1. Curbs, Dikes and Gutters

Curbs, dikes and gutters are more fully discussed in the next section (Mechanical Stabilization of Oversteepened Slopes) as a means to provide a slope toe bench. They are also used to direct runoff away from erodable surfaces to appropriate discharge points such as drop inlets, rock-lined ditches, or a properly sized percolation facility.

Figure VIII-10 shows the gully formation that occurred when street drainage was allowed to flow uncontrolled down an unstable fill slope. During a 15-year period it is estimated that at least 1,800 metric tons were eroded from the slope.

Proper maintenance of curbs, dikes and gutters is essential. Figure VIII-11 shows the result of a breach in a dike at Rubicon Properties. Over one hundred metric tons of soil were removed from this unstable fill slope in one snow melt season.

2. Drop Inlets

The usual purpose of a drop inlet (D.I.) structure is to collect and direct, via underground conveyance, storm water runoff to an appropriate discharge point. An important addition to drop inlet design (See Figure VIII-12) is provision for settling and retention of suspended sediments. Actual sizing for such a structure is dependent upon:

- size of runoff area tributary to the drop inlet,
- expected suspended sediment load to the drop inlet,
- frequency of runoff conditions, and
- expected frequency of maintenance.

Design and spacing of such structures should be conducted by a registered civil engineer. Effluent from the drop inlet should be directed to non-erodible conveyance facilities and infiltration structures. A good rule

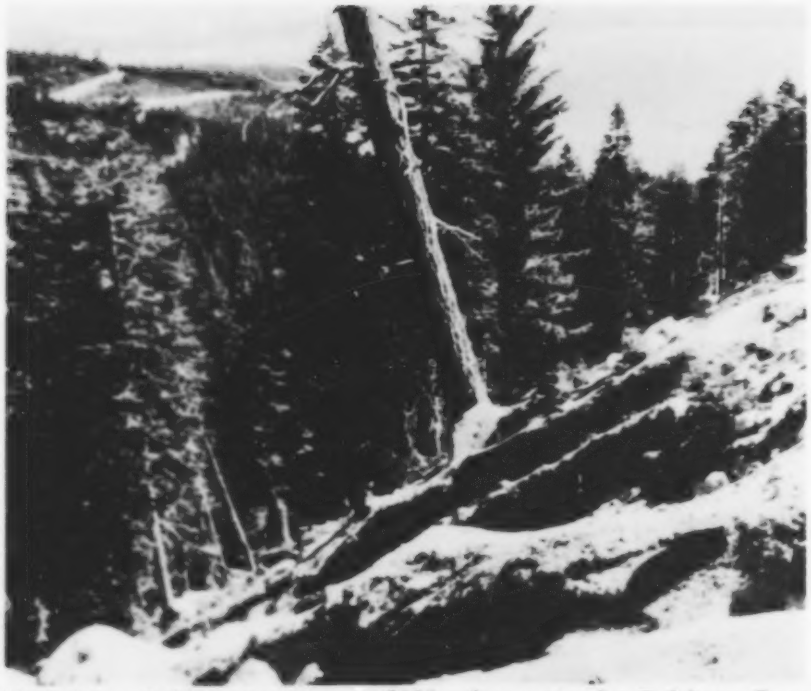


Figure VIII-10. Gully erosion on fill slope at the Rubicon Properties erosion control project site resulting from poor drainage control, and lack of vegetation.

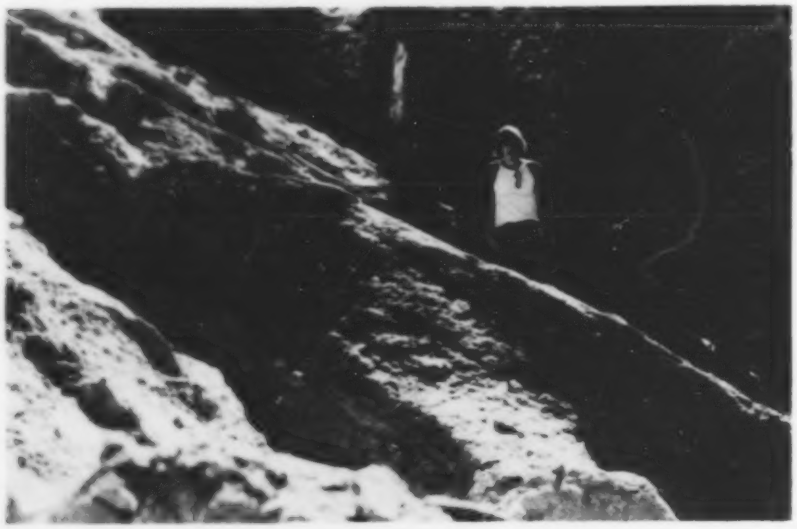


Figure VIII-11. Severe erosion on fill slope at Rubicon Properties erosion control project site caused by a break in an A-C dike.

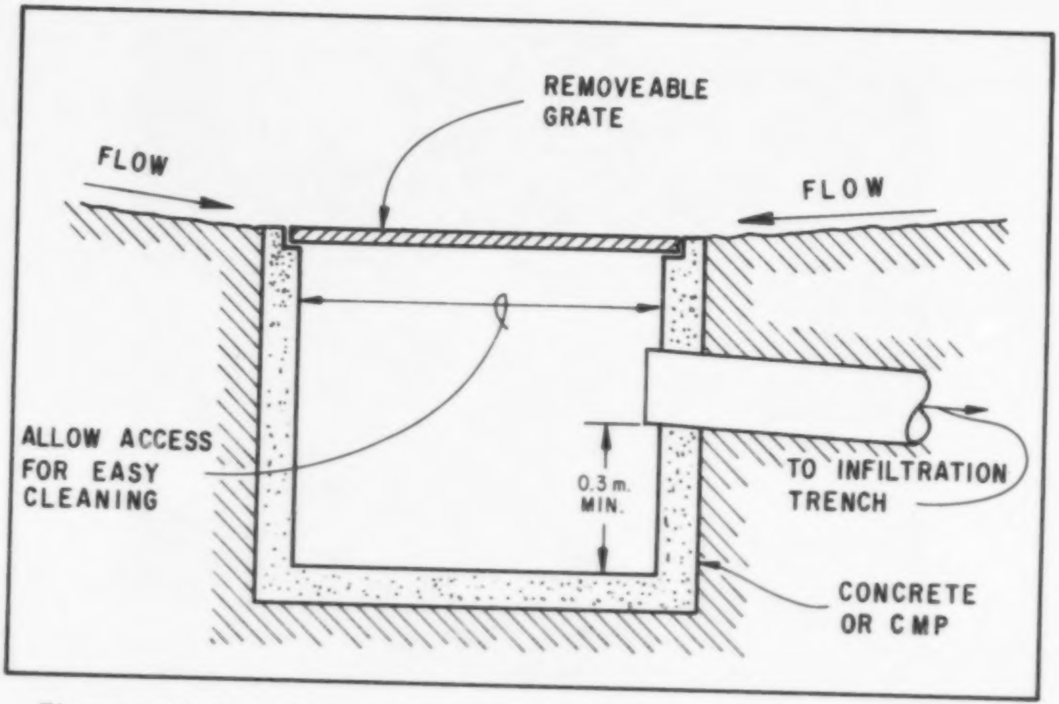


Figure VIII-12. Typical drop inlet installation designed to settle and trap transported sediments.

of thumb would be to design drop inlet structures to settle and remove 90 percent of anticipated suspended sediments at design flow conditions.

If oil and grease in the storm runoff is expected to cause additional problems, "T" type entrance to the effluent line must be provided. This will effectively block oil, grease and other low density contaminants from being discharged to surface water or subsequent infiltration facilities.

The effectiveness of drop inlet structures designed to settle suspended sediments will quickly diminish if they are not adequately maintained. This is particularly true if the drop inlet collects runoff from eroding surfaces.

3. Drainage Channels

If the collected runoff must be directed overland to an appropriate discharge point, the use of rocklined (or similar) drainage channels is recommended. The reasons for this are:

- aesthetic natural appeal,
- non-erodible surface,

- low cost, and
- high surface "roughness" which dissipates the erosive energy of the flowing water.

The last factor, that is energy reduction of the flowing water, can be further enhanced by drop structures or energy dissipators.

Use of rock-lined channels is limited to gentle slopes. For steeper slopes other methods such as sectional downdrains, or culverts, as pictured in Figure VIII-13, must be used. Figure VIII-14 depicts the type of problem that can arise if collected drainage waters are allowed to flow uncontrolled over an erodible surface. Approximately 20 metric tons of soil were eroded in a single snow melt season at this site. Figure VIII-15 depicts a rock lined channel which was designed and installed to correct this problem.

Costs of rock lined channels are dependent upon size, equipment access, and availability of rock material. The rock channel pictured in Figure VIII-15, which is approximately 30 cm deep, 100 cm wide, 100 meters long, located in a readily accessible area, and constructed of readily available stone from adjacent areas, would cost $12.36 per meter based upon the assumptions listed at the beginning of this section. If rocks had to be purchased and transported to the site the cost would be expected to increase by an additional $1.75 per meter.

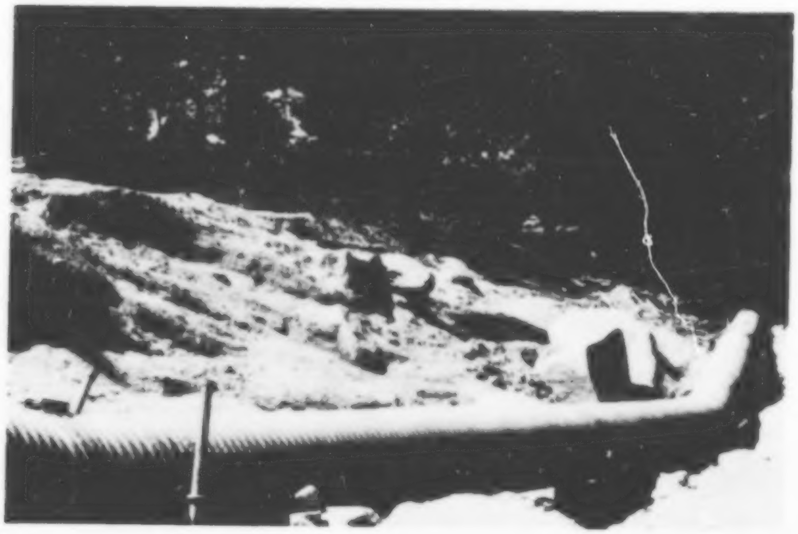


Figure VIII-13. Corrugated metal pipe used to direct drainage across highly erodible fill slope.

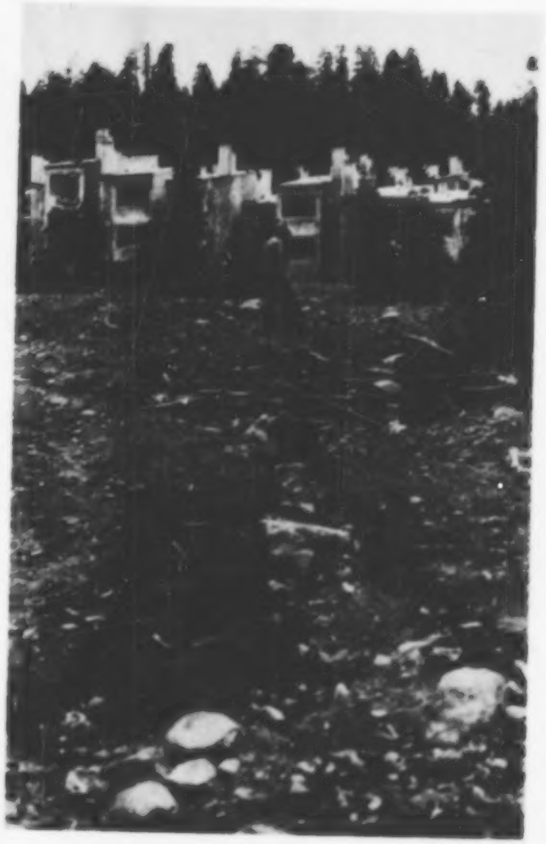


Figure VIII-14. Erosion caused by uncontrolled drainage flowing across highly erodible fill area.

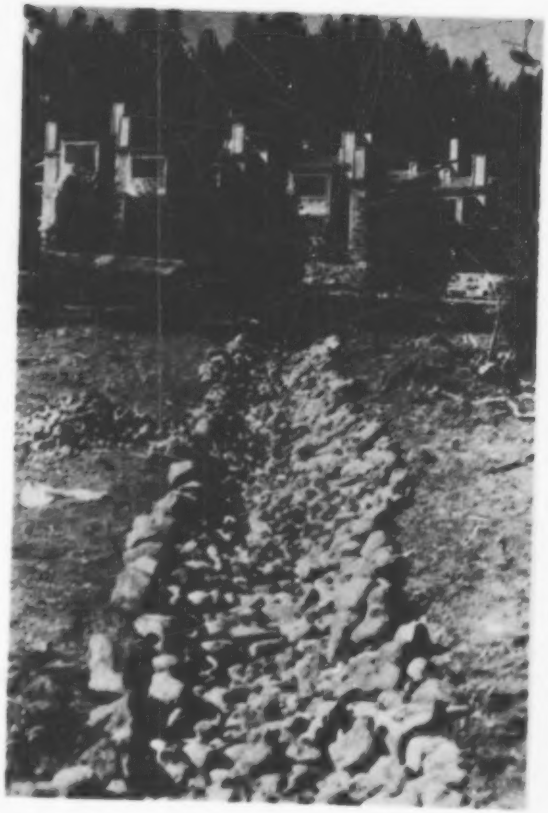


Figure VIII-15. Rock lined drainage channel designed to correct problem pictured in Figure VIII-14.

If only infrequent very low flows are directed to overland channels on very gentle slopes, an alternative to rock lining may simply be channel vegetation. Vegetative techniques are described in a subsequent section entitled "Permanent Vegetative Erosion Control". Methods which are applicable for vegetating small channels include:

- willow staking,
- contour wattling,
- seeding with mulch nets and blankets, and
- seeding with fiberglass roving.

4. Water Bars

Water bars can be effectively employed to prevent storm runoff from developing and accumulating eroded sediment on heavily travelled or abandoned dirt roads and trails. By breaking up an extended erodible surface into a series of smaller areas with separate drainages, storm runoff flow velocities and quantities can be significantly reduced. Figure VIII-16 depicts a typical water bar installation on a heavily travelled dirt road at the Northstar erosion control project site. Prior to installation of the pictured water bar, road drainage resulting from snow melt and rainfall flowed down the road and discharged directly to a stream which passed under the road at a low spot. Heavy vehicle traffic pulverized the road surface resulting in a sediment-laden discharge to the

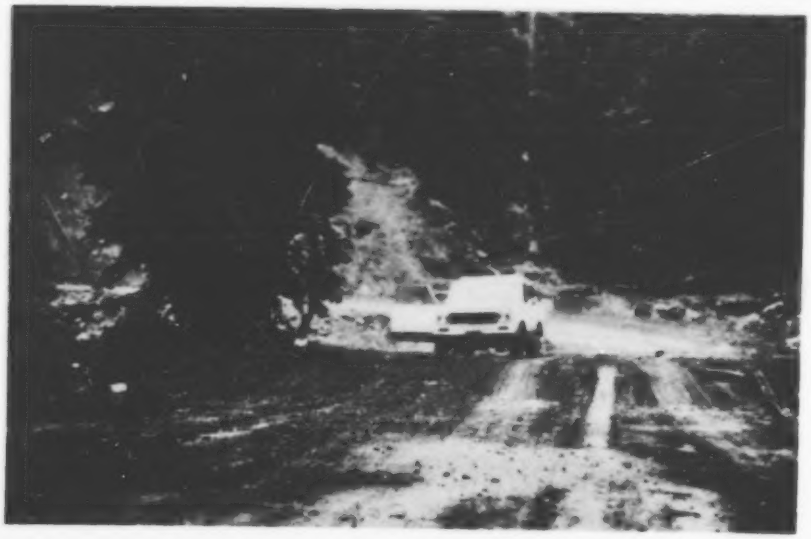


Figure VIII-16. Water bar installation on heavily travelled dirt road at Northstar.

stream. After construction of the water bar pictured in Figure VIII-16, road drainage was diverted to a densely vegetated area which effectively intercepted and filtered the drainage water prior to dishcarge to the stream.

Good judgement must be used in the design and location of water bars. Figure VIII-17 depicts an extremely close spacing of large water bars on an abandoned dirt road at the Rubicon Properties erosion control project site. Prior to the installation of the pictured water bars, erosion from this dirt road was extreme. Furthermore, accumulated runoff had caused increased erosion down gradient from the road. Not only will such large water bars or similar barriers act to divert surface drainage to more stable areas, but they will also discourage further vehicular use of the road which could disrupt revegetation measures. As a guide, Figure VIII-18 may be used to determine the maximum spacing for water bars for various slope gradients and soil erosion hazard ratings. The data shown in Figure VIII-18 is based upon information prepared for use by the U. S. Forest Service (15, 47). Erosion hazard rating is based upon the area below the road or tract.

In addition to proper spacing as indicated in Figure VIII-18, water bars should discharge into undisturbed areas, rock ground, or areas well protected with vegetative cover. Water bars should also be located to accept and redirect runoff from lateral disturbed areas or other tributary areas.

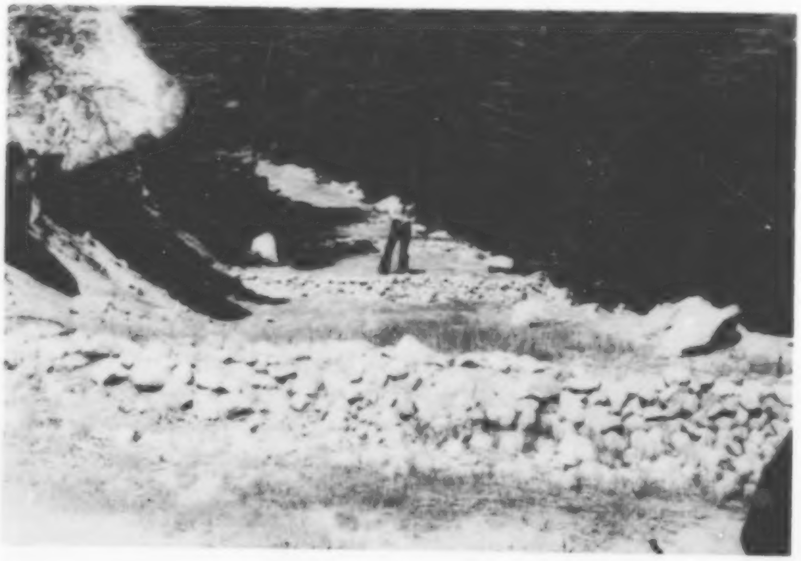


Figure VIII-17. Closely spaced water bars on abandoned dirt road.

5. Infiltration Trenches

The best approach to reducing erosion generated by storm runoff is to percolate drainage from all impervious surfaces. In most instances impervious surface runoff cannot be discharged to surrounding undisturbed areas for percolation without causing substantial erosion problems. The Regional Water Quality Control Board, Lahontan Region, requires an adequately designed percolation trench for runoff control in the California portion of the Lake Tahoe basin. Figure VIII-19 depicts a typical cross section design for an infiltration trench. In addition to the configuration depicted in Figure VIII-19, a well designed infiltration trench will also have a provision for overflow to a storm water system in the case of:

1. failure of the infiltration trench due to clogging by deposited sediments, or

2. storm intensities greater than the "design storm".

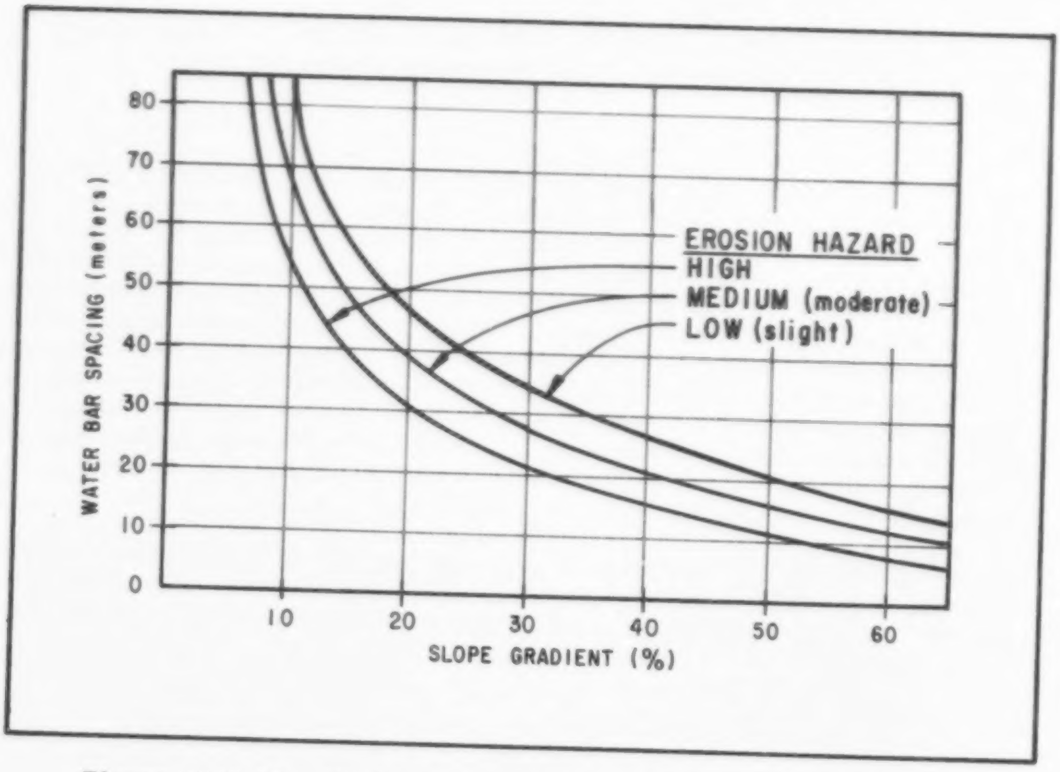


Figure VIII-18. Maximum water bar spacing for various slope gradients and erosion hazard ratings.

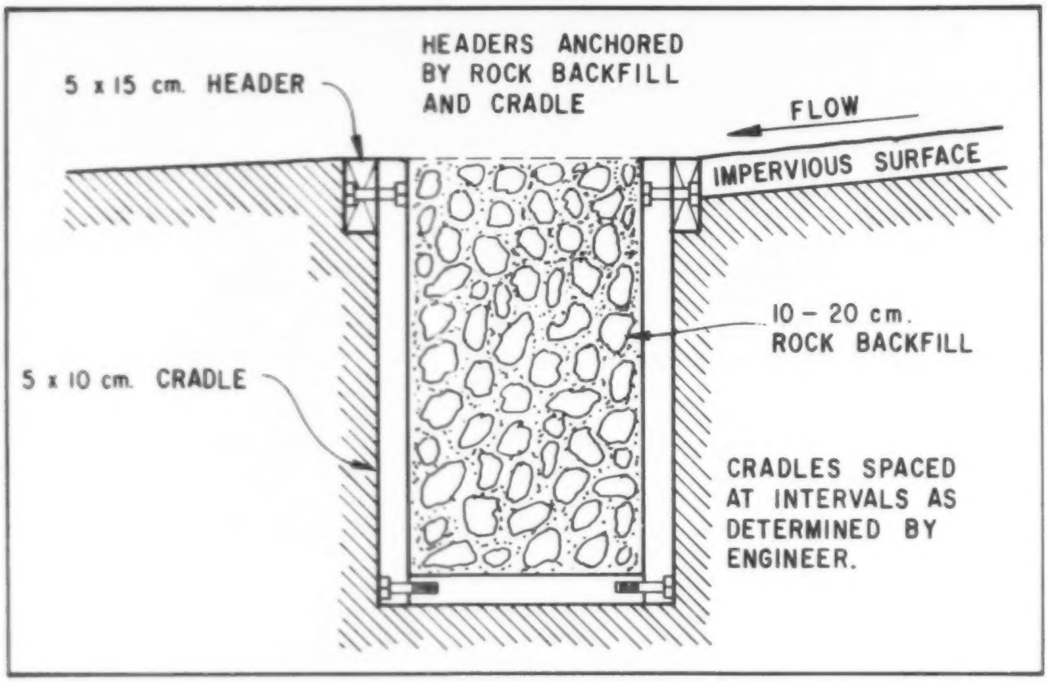

HEADERS ANCHORED
BY ROCK BACKFILL
AND CRADLE
5 x 15 cm. HEADER
FLOW
IMPERVIOUS SURFACE
10 - 20 cm.
ROCK BACKFILL
5 x 10 cm. CRADLE
CRADLES SPACED
AT INTERVALS AS
DETERMINED BY
ENGINEER.

Figure VIII-19. Typical infiltration trench design for percolation of storm runoff from impervious surfaces.

Infiltration trench life expectancy can be vastly increased by the use of sediment traps to remove suspended sediments before discharge to the trench. However, drop inlets or similar structures placed as an intermediate treatment device between the impervious surface and the infiltration trenches cannot be expected to be totally effective in removing all sediment from the storm runoff. Thus, any infiltration trench installation should provide for removal of the rock backfill and accumulated sediment depositions. The removed rock backfill can be washed and reused or replaced with new rock. If oil and grease deposits, which could clog and reduce trench effectiveness are anticipated, adequate attention must be given to the separation of such substances from the runoff prior to discharge to the trench.

The final design of infiltration trenches and other appurtenances should be left to a professional engineer. The Regional Water Quality Control Board, Lahontan Region, uses the following relationship as a guideline for the sizing of infiltration trenches (48):

$$L = \frac{A \cdot Q}{[(W \cdot P) + .67\,(D \cdot P)] + [.33\,(D \cdot W)]} \qquad \text{(Equation VIII-1)}$$

where: A = area of impervious surface contributing runoff to infiltration trench (square meters)
L = length of the trench (meters)
W = width of the trench (meters)
D = depth of the trench (meters)
P = percolation rate of the soil in which the trench is placed (cm/hr)
T = storm duration (hours)
Q = unit runoff from impervious surface area (cm). The value of Q is determined by using the SCS triangular hydrograph method (49, 50, 51) as follows:

$$Q = \frac{(R-I)^2}{(R - I + S)} \qquad \text{(Equation VIII-2)}$$

R = depth of rainfall (cm)
I = initial abstraction which is the maximum amount of rainfall that can be absorbed on the impervious surface without producing runoff. It is empirically assumed that $I = 0.25$ (cm).
S = maximum potential difference between R and Q, accounting for minor permeability of an impervious surface. $S = .508$ (cm) for precipitation ranging from 0 to 30.5 centimeters.

The reasons that the SCS method was chosen over the somewhat simpler rational method include:

1. it is still simple and relatively straightforward,

2. it is based upon a "triangular hydrograph" and therefore acknowledges the variation in runoff rates during a typical storm,

3. it accounts for surface retention (surface wetting) or "initial abstraction" which the rational method does not consider.

The Regional Water Quality Control Board, Lahontan Region, requires infiltration trenches on new projects in the Tahoe area to have a 95 percent reliability. Therefore, infiltration trenches are designed such that the probability of overtopping is no more than five percent. Since the probability of an event being equalled or exceeded at any time is equivalent to the inverse of the return period of the event, a 20-year storm is used as a basis for design. Furthermore, it is assumed that a one-hour duration rainstorm is the most critical runoff event. Other assumptions which are used with the above analysis include:

- trench sidewall percolation is one-third that of the trench bottom per unit area, and
- the porosity of the rock backfill used in the trench is .33.

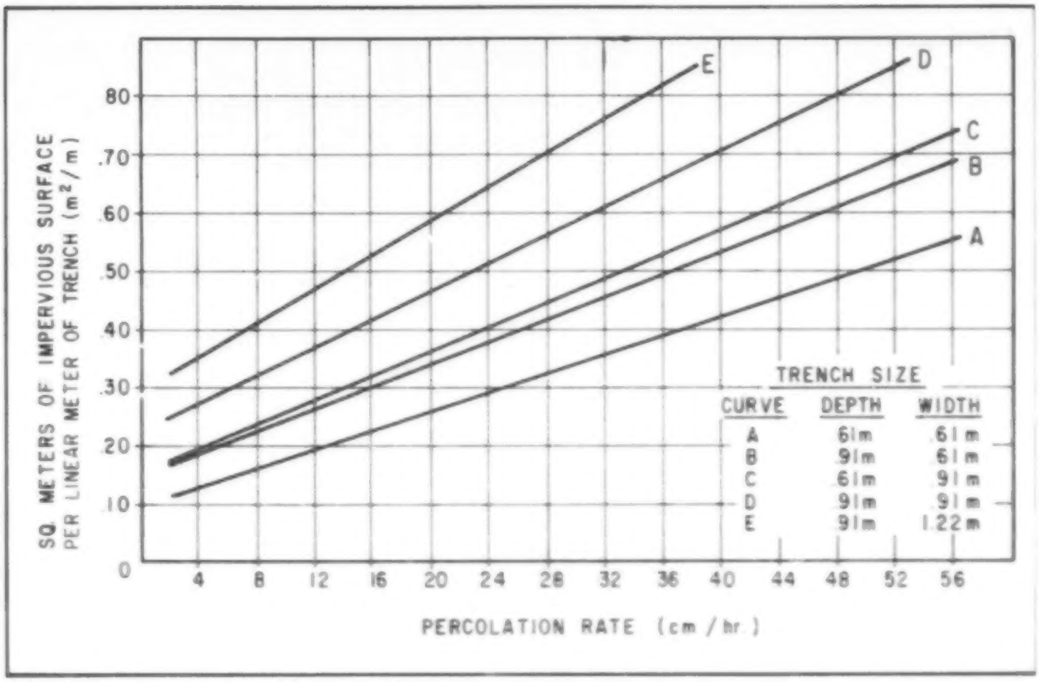


Figure VIII-20. Infiltration trench sizing diagram.

Figure VIII-20 is a graphical representation of Equation VIII-1 for a variety of infiltration trench widths and depths for South Lake Tahoe. Basically, the wider and/or deeper the trench, less trench length is needed to infiltrate runoff from a given area. For the Lake Tahoe vicinity of the Sierra Nevada the following are acceptable precipitation values for a design 1-hour rainstorm with at least a 95 percent reliability.

	R (centimeters)
South Lake Tahoe	1.78
North Lake Tahoe	1.91
Truckee	1.30

6. Sediment Retention Basins

The purpose of a sediment retention basin is to trap and retain sediment generated by construction activities. Construction of permanent sediment retention basins is the "last line of defense" against off-site sediment pollution. They should be utilized only if drainage control and stabilization of disturbed areas prove inadequate.

Figure VIII-21 depicts a sediment basin located in a poorly designed and developed subdivision within Lake Tahoe Basin. Due to the large area of

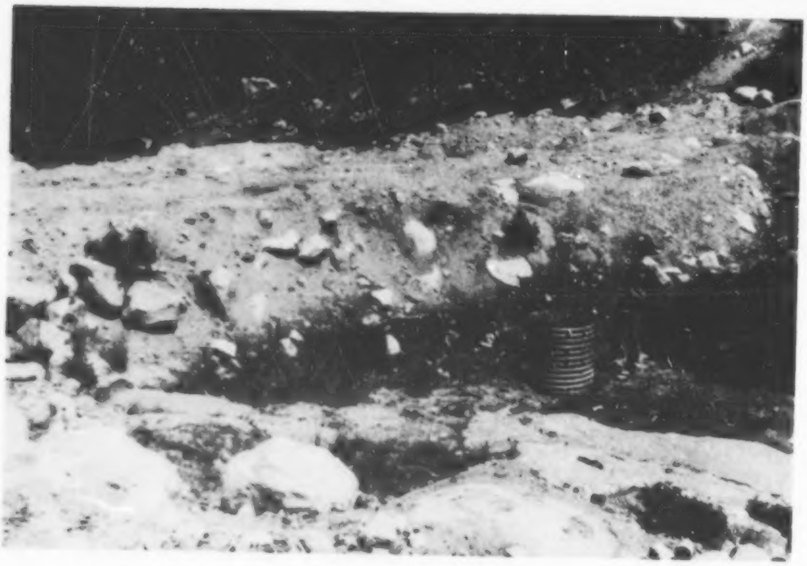


Figure VIII-21. Suspended sediment settling basin for storm runoff control. Continued maintenance is required to assure adequate settling capacity

disturbed slopes and the considerable runoff from impervious surfaces, the pictured sediment basin is the most practical means of preventing sediment pollution.

When properly designed, constructed, and maintained sediment basins are capable of removing a high percentage of both coarse and fine suspended sediment from storm water runoff. Large basins require formal design by a professional civil engineer.

Sediment basins must be located so as to maximize effectiveness, minimize cost, minimize additional disturbance and facilitate access for maintenance. Detailed design criteria are completely dependent upon site specifics. Actual design of settling basins may vary considerably from location to location. When possible, however, the following criteria should be considered:

- hydraulic capacity sufficient to handle a 50-year storm,
- overflow rate sufficient to settle and retain 90 percent (by weight) of the anticipated suspended sediments in the runoff from the tributary area in a 20-year, 1-hour storm,
- dam embankments completely stabilized with side slopes no steeper than 2:1,
- easy access for maintenance and cleanout of deposited sediments.

7. Drainage Control Cost-Effectiveness Analysis

No attempt has been made to determine the relative cost and effectiveness of drainage and runoff control techniques. The primary reason for this being that the State Board was unable to construct and specifically demonstrate the majority of these methods at the project sites due to their relatively high cost. Furthermore, the situations encountered at the project sites were not conducive to construction and effective application of the majority of these methods.

E. Mechanical Stabilization of Oversteepened Slopes

Oversteepened, unrevegetated slopes, with inadequate drainage control, are perhaps the most significant source of eroded material in the Tahoe-Sierra region of California - and the most difficult to control. In most cases, current governmental controls and grading ordinances will prevent the generation of highly erosive, oversteepened slopes in the future. The problem therefore, is centered around the correction of existing problem areas which were created prior to the establishment of effective controls. Large oversteepened areas are widespread and clearly evident throughout the Tahoe-Sierra. Large cuts and fills can be found adjacent to federal, state, county, and private highways and roads. Similarly, quarries, gravel pits, and building construction have left large areas of unstable eroding slopes.

Stabilization of bare soil areas, as addressed in this report, has emphasized revegetative techniques as the cheapest and most effective method of controlling erosion. Gently sloping bare soil areas usually require only simple seeding or planting; oversteepened slopes require either reduction of slope steepness or extensive efforts to mechanically stabilize the slope face until revegetative plantings are sufficiently established.

In many instances, reworking an oversteepened slope to form a less severely sloping area may be impractical. Figure VIII-22 depicts two slope profiles which illustrate this point. In Case "A" the previous steeply cut slope (dashed line) is located in an area where the natural undisturbed terrain is gently sloping. Thus, by constructing a small retaining structure at the slope toe and reworking the face to a 1½:1 slope, the total slope length is only slightly increased. Case "B", differs only in the slope of the undisturbed natural terrain above the cut slope face. If the same small retaining structure is provided and the cut face is reworked to a 1½:1 slope, the overall slope length is increased by 300 percent. The only alternatives are to:

1. construct a higher retaining structure,
2. move the slope toe further out into the roadway,
3. rework the cut face to an angle somewhat steeper than 1½:1, or
4. combination of the above.

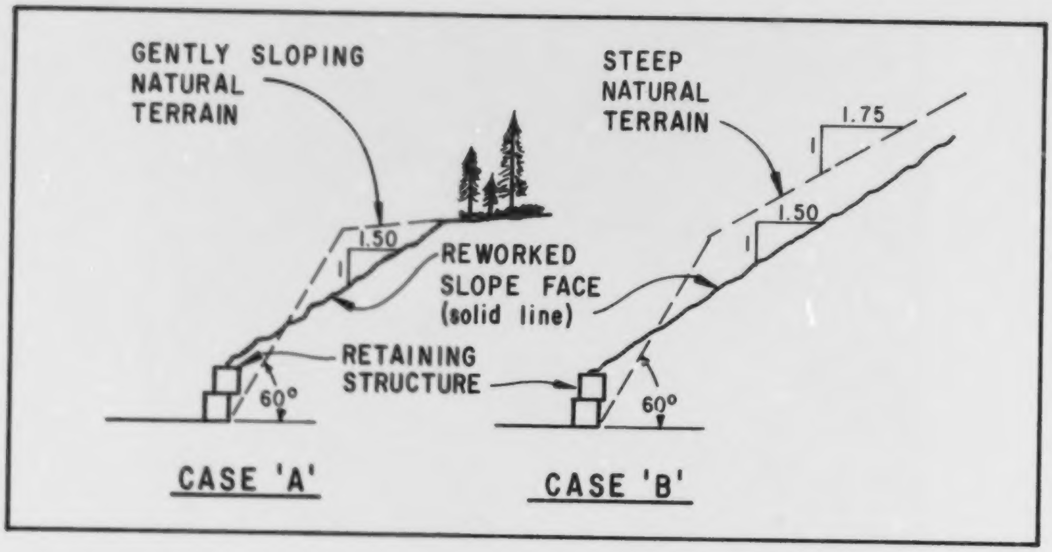


Figure VIII-22. Cut slope reworking. The amount of reshaping is dependent upon slope of the natural terrain above the road cut.

The majority of this section is devoted to describing specific ways in which steep slopes may be sufficiently reworked and stabilized to allow revegetation. The last part of this section is devoted to a discussion of other mechanical slope stabilization techniques which do not rely entirely on revegetation to provide ultimate erosion control. By incorporating the following procedures, major slope reworking, leveling, and lengthening should not be required in most instances.

1. Curbs and Dikes for Bench Construction

Many existing oversteepened cut slopes, such as pictured in Figure VIII-23 are continually undercut at the slope toe by uncontrolled drainage water or road maintenance crews.

In these cases, either slope toe foundations are non-existent or they have been placed too close to the slope to provide sufficient protection. The slope toe pictured in Figure VIII-23 does have an asphalt-concrete (A-C) dike and gutter. However, because of the excessive steepness of the overlying unrevegetated slope and the dike's close proximity to the slope, the dike and gutter are continually buried by sediment eroded from the slope face. During every runoff event the deposited material is readily swept away, only to be replaced once again by further deposition of material eroded from the slope face.

At the erosion project sites, much of the recurring sediment deposition at the slope toe was directly attributable to frost heaving and wind

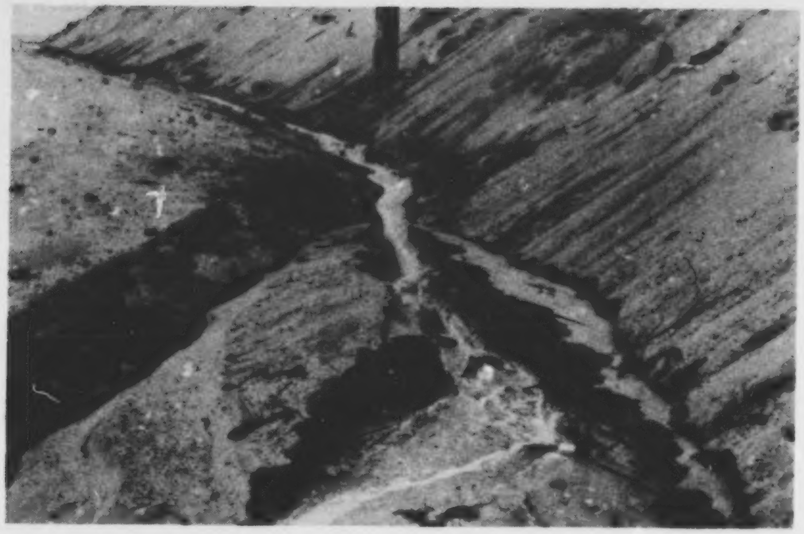


Figure VIII-23. Sloughed and eroded soil material at toe of steeply eroding road cut at the Rubicon Properties erosion control project site.

erosion, rather than erosion induced by running water. This was particularly true when the unvegetated slopes were steeper than the angle of internal friction (angle of natural repose) of the local soil. At the Rubicon Properties project the soil was decomposed granite for which the angle of internal friction is approximately 35 degrees (1.5:1). The soil at the Northstar project site was comprised primarily of volcanic material also with an angle of internal friction of about 35 degrees.

The easiest and least expensive manner of correcting problems created by unstable slope toes at the project sites was to move the slope toe further away from the slope face and protecting the toe from further erosion. Gutters and dikes originally placed too close to a steep (2:1 or greater) slope were moved away from the toe and backfilled to create a less steeply sloping (less than 2:1) bench. Figure VIII-24 illustrates the bench which is created by moving the curb and gutter a sufficient distance away from the toe of the original slope. The eroding soil material which would slough over the original curb and into the gutter is shown as the cross-hatched area in the figure.

A reconstructed gutter will not be effective in the long run if additional sloughing is not controlled. The remainder of the slope face must be stabilized.

Maintenance of curbs and gutters is essential, particularly in harsh climates such as at Tahoe. A total of 1,225 meters of reconstructed curbs and gutters were installed at the Rubicon Properties project site

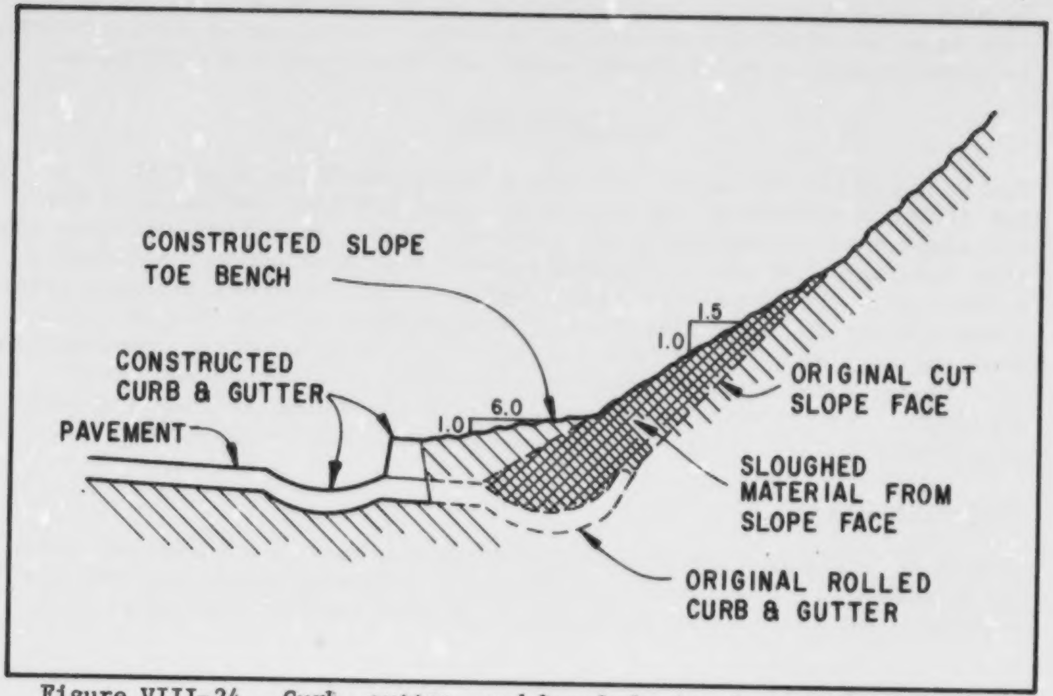

CONSTRUCTED SLOPE TOE BENCH
CONSTRUCTED CURB & GUTTER
PAVEMENT
1.5
1.0
6.0
1.0
ORIGINAL CUT SLOPE FACE
SLOUGHED MATERIAL FROM SLOPE FACE
ORIGINAL ROLLED CURB & GUTTER

Figure VIII-24. Curb, gutter, and bench design for stabilizing the toe of a steeply eroding cut slope.

in 1976. The equivalent cost (see cost assumption at beginning of this section of this type of installation ranged from $12.32/meter to $19.28/meter. The average unit costs for installation of curbs and gutters at the Rubicon Properties project site are as follows:

1225 Meters of Reconstructed Curbs and Gutters

	Equivalent Unit Cost ($/meter)
Labor (at $16.25/hr)	$7.77
Equipment (CalTrans rental rate)	4.56
Material (.23 metric tons/meter at $14.30/metric ton)	3.29
TOTAL AVERAGE COST	$15.62/meter

Approximately one-third of the $15.62/meter unit cost of curb and gutter work represents the cost of grading and resurfacing prior to placement of the curb. Two thirds of the cost is for the actual placement of the curb. If a considerable amount of original paving or curb and gutter structures must be removed, the unit cost would be increased substantially.

In many cases the simple reconstruction of a curb and gutter system further from the slope toe may not be feasible. The range of alternatives includes construction of breast walls and other retaining structures.

2. Breast Walls

Breast walls may be used to provide a slope toe "foundation" if it is not feasible to reconstruct a curb and gutter system further away from the slope toe. Breast walls do, however, have a considerably higher cost than does the curb and gutter replacement mentioned above. A definite advantage of the large rock breast walls is that they are imposing structures and are far less likely to be damaged by road maintenance equipment than are low-lying dikes. In all cases, plans for the construction of a breast wall structure must be supervised by a registered civil engineer. The possibility of wall failure and damage to life and property requires that walls be carefully designed and constructed.

Rock Breast Wall

Figure VIII-25 shows the typical construction profile of a breast wall using large (.25 - 1.0 meter) rocks. The following specifications are suggested for use in the construction of this type of structure:

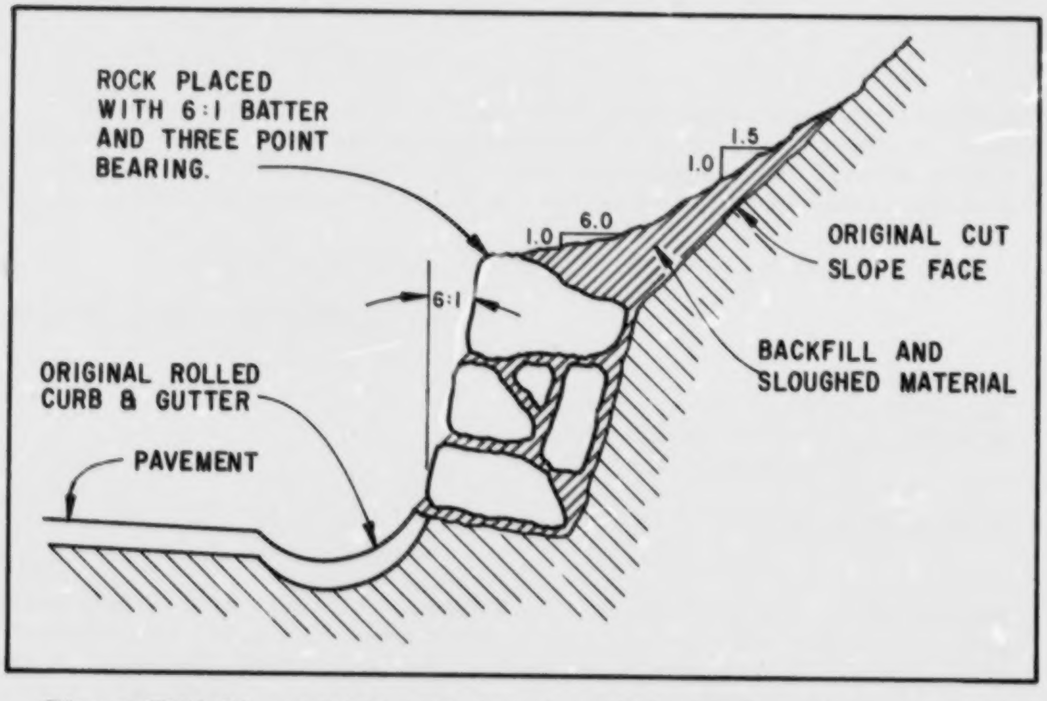

ROCK PLACED
WITH 6:1 BATTER
AND THREE POINT
BEARING.
1.5
1.0
1.0
6.0
6:1
ORIGINAL CUT
SLOPE FACE
BACKFILL AND
SLOUGHED MATERIAL
ORIGINAL ROLLED
CURB & GUTTER
PAVEMENT

Figure VIII-25. Typical rock breast wall design for the toe of a steeply eroding slope.

a. Rock breast walls shall be 1.0 to 1.5 meters high.

b. Rock used shall be between .25 and 1.0 meter in diameter.

c. The rock breast wall shall be laid upon solid foundation material or well-tamped earth if such earth would not be subject to erosion.

d. A minimum amount of excavation into the slope shall be performed to provide a foundation for the rock breast wall. The breast wall may not be placed such that it reduces the road surface to less than the minimum required dimensions.

e. The rocks shall be laid with at least a three point bearing on the foundation material or on previously laid rocks.

f. The rocks shall be placed such that their centers of gravity are as low as possible, with the bedding planes sloping inward toward the slope toe.

g. The rock breast wall shall be constructed such that the external wall face has a 6:1 batter.

h. As the rocks are placed, fill shall be laid behind and around the rocks and tamped thoroughly.

i. In addition to fill, live willow branches shall be placed in the interstices of the rock wall as it is constructed. The basal ends of the willow branches shall extend into the backfill behind the rock breast wall.

j. The rock breast wall shall be constructed such that a bench with a maximum slope of 2:1 and a minimum slope length of two meters can be filled behind the rock breast wall.

k. The top layer of rocks must be placed in a closely adjacent and continuous manner to minimize gaps.

l. In the case of rock breast wall constructed adjacent to a paved or impervious surface, drainage system shall be placed at the outside toe of the rock breast wall directing drainage waters to an appropriate disposal area and preventing erosion of the foundation material and undercutting the rock breast wall.

The above sample specifications are intended only as a guide, and must be modified to fit the particular situation.

Gabions

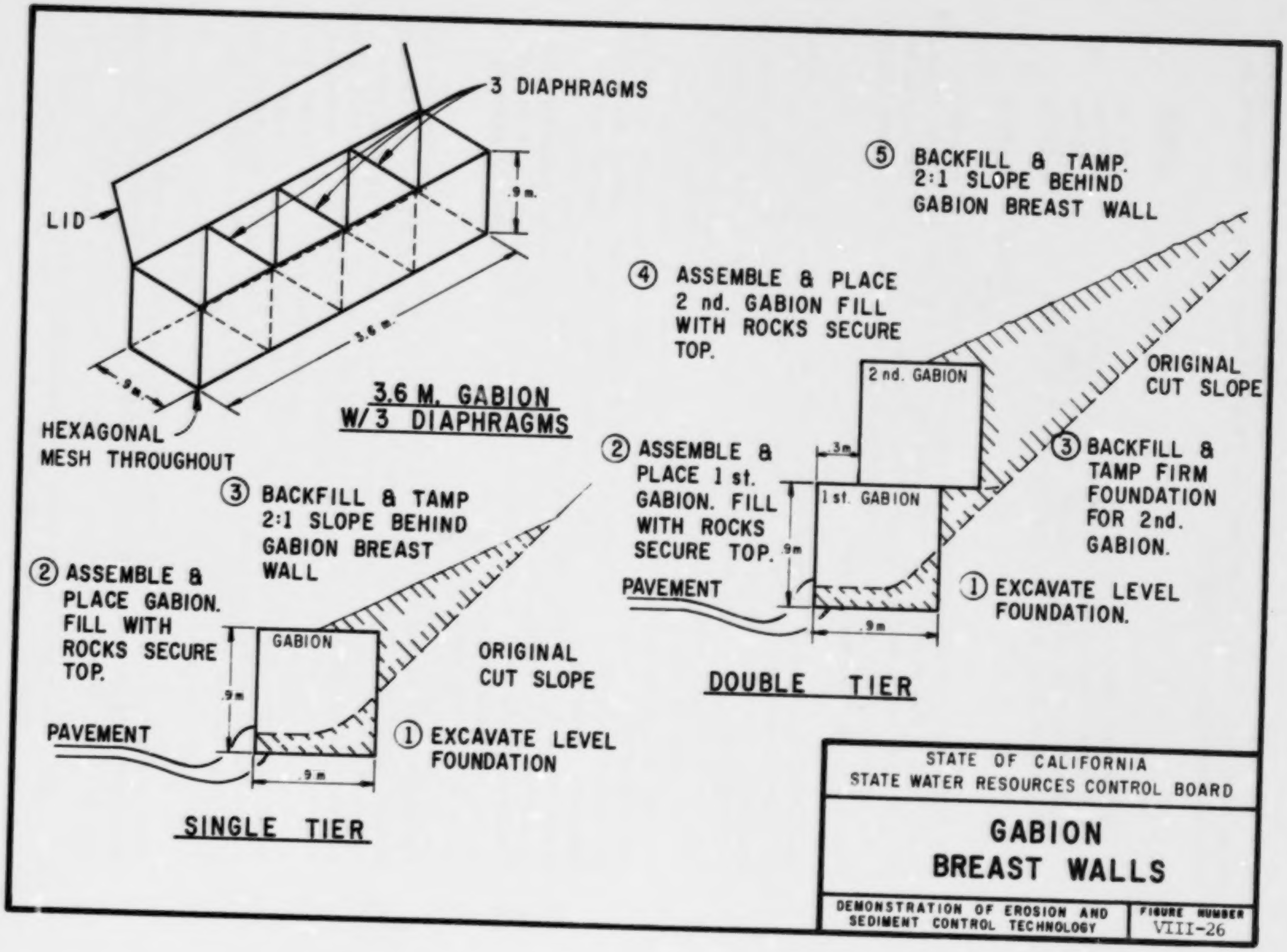
In addition to the use of large rocks for the construction of breast walls, gabions with cobblestone sized rocks may also be used. Gabions are rectangular compartment containers fabricated from a triple twisted hexagonal mesh of heavily galvanized steel wire. Figure VIII-26 depicts a typical one tier and two tier gabion breast wall installation. Excavation of the site for the placement of the gabions is similar to the procedure described for rock breast walls. For easy handling and shipping, gabions are supplied folded into a flat position and bundled together. Each gabion is readily assembled by unfolding and binding together all vertical edges with lengths of connecting wire stitched around the vertical edges. The empty gabions are placed in position and wired to adjoining gabions. They are then filled with cobblestone sized rock (10 - 30 centimeters in diameter) to one third their depth. Two connecting wires are then placed in each direction bracing opposing gabion walls together. The connecting wires prevent the gabion baskets from "bulging" as they are filled. This operation is repeated until the gabion is filled. After filling, the top is folded shut and wired to the ends, sides and diaphragms. During the filling operation live rooting plant species, such as willow, may be placed among the rock material similar to the operation described for rock breast walls. If this is done, some soil should be placed in the gabions with the branches and the basal ends of the plants should extend well into the backfill area behind the gabion breast wall.

The total labor requirement for the construction of a gabion structure is estimated by one manufacturer to vary from 1.5 to 2.0 person-hours per cubic yard (2.0 to 2.6 person-hours per cubic meter). At the Rubicon Properties project site gabion structures were installed using low cost unskilled labor at a rate of 1.66 person-hours per cubic yard (2.17 person-hours per cubic meter), including the loader operator's time in filling the gabion structure with rock.

The simplest gabion structure is a .91 meter high wall using one tier of gabions. A second tier of gabions can be placed on top of the first tier and set back 30 centimeters without any significant design constraints. Gabion walls which are higher than two tiers (1.8 meters), however, do require significant additional design constraints. Such higher "retaining wall" structures must be well designed under the supervision of a registered civil engineer. The higher the retaining wall structure, the more likely it is to fail unless it is well designed. As higher tiered walls are designed and used, the basal foundation of the wall must be increased and/or counterforts must be used to brace the wall against the tipping force of the material retained behind it. In all cases, the retaining wall must be structured such that the "righting moment" of the wall is at least 1.5 times the "tipping moment" created by the retained material.

Breast Wall and Retaining Wall Costs

Breast walls were used extensively at the Rubicon Properties project site as a means of stabilizing the toe of oversteepened, eroding slopes. In some cases the average slope steepness was as high as 1:1. In the few instances where the eroding slopes were steeper than 1:1, 2.7 meter gabion retaining walls were used to reduce the average slope steepness


3 DIAPHRAGMS
LID
.9 m.
3.6 m.
.9 m.
HEXAGONAL MESH THROUGHOUT
3.6 M. GABION W/3 DIAPHRAGMS
⑤ BACKFILL & TAMP. 2:1 SLOPE BEHIND GABION BREAST WALL
④ ASSEMBLE & PLACE 2 nd. GABION FILL WITH ROCKS SECURE TOP.
2 nd. GABION
ORIGINAL CUT SLOPE
② ASSEMBLE & PLACE 1 st. GABION. FILL WITH ROCKS SECURE TOP.
.3m
1 st. GABION
③ BACKFILL & TAMP FIRM FOUNDATION FOR 2nd. GABION.
.9m
PAVEMENT
① EXCAVATE LEVEL FOUNDATION.
.9m
DOUBLE TIER
③ BACKFILL & TAMP 2:1 SLOPE BEHIND GABION BREAST WALL
② ASSEMBLE & PLACE GABION. FILL WITH ROCKS SECURE TOP.
GABION
ORIGINAL CUT SLOPE
.9m
PAVEMENT
① EXCAVATE LEVEL FOUNDATION
.9m
SINGLE TIER

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

GABION
BREAST WALLS

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER
VIII-26

above the wall to 1:1 or less. The following breast walls and retaining walls have been installed at Rubicon Properties as part of the Erosion Control Demonstration Project:

		Length
1.3 meter high rock breast wall		350 m.
0.9 meter high gabion breast wall (1 tier)		1500 m.
1.8 meter high gabion breast wall (2 tier)		450 m.
2.7 meter high gabion retaining wall (3 tier)		200 m.
	TOTAL	2500 m.

In addition to the above walls, two sections, totalling 50 meters in length, of a 0.6 meter high rock wall were constructed at the Northstar project site using manual labor only. The rocks used for the Northstar walls were up to 40 cm in diameter and weighed up to 50 kilograms, otherwise known as "two-man rocks".

Table VIII-2 presents the equivalent unit materials, equipment and labor costs for the construction of a variety of breast wall structures. The commercial delivered price of all rock at the project site is assumed to be $8.40 per ton. A 0.9 meter high wire mesh gabion basket costs approximately $9.80 per meter of length. Little equipment was required for construction of the 0.6 meter "two-man" rock breast wall due to the entire rock placement operation being conducted by manual labor. For the larger rock breast walls, a heavy duty loader with a cost of $27.00 per hour is required continuously. In the case of the gabion structures, however, the heavy duty loader is required for a small percentage of total construction time, for the gabion filling operation only. If organized efficiently, the filling operation can proceed quite rapidly compared to the rest of the gabion construction procedure. As stated at the beginning of this section, the total cost of labor is assumed to be $16.25 per person-hour.

The total cost of any particular wall type is greatly influenced by the highly variable unit cost of materials and labor. For example, if large boulders suitable for rock breast wall construction are present at a prospective erosion control site, the total cost of 1.0 meter rock breast wall could be reduced to $50.00 per meter. Similarly, if an unskilled, low cost labor force (e.g. $5.00 per person-hour total unit labor cost) could be used to set up and wire gabions together, the total cost of a 0.9 meter gabion breast wall could be reduced from $58.61 per meter to less than $45.00 per meter. Less expensive sources of rock could further reduce the gabion structure's unit cost.

Concrete gravity walls, or counterforted reinforced concrete walls, were not used at either the Rubicon Properties or Northstar project site for two primary reasons:

a. their relatively unnatural appearance, and
b. their extremely high costs.

TABLE VIII-2

COMPARATIVE BREAST WALL CONSTRUCTION EQUIVALENT COSTS*

		UNIT COST($/METER)		
WALL TYPE	MATERIALS	EQUIPMENT	LABOR	TOTAL
0.6 meter "two-man" rock breast wall	4.00	2.91	22.94	29.85
1.0 meter rock breast wall	11.04	22.62	27.50	61.16
1.35 meter rock breast wall	13.80	28.28	34.38	76.45
0.9 meter gabion breast wall	22.40	5.71	30.50	58.61
1.8 meter gabion breast wall	44.80	11.42	61.00	117.22
2.7 meter gabion retaining wall	72.80	18.56	99.13	190.48

* Based upon documented construction at project sites and stated assumptions at front of this section.

A 1.0 meter concrete gravity wall, for example is estimated to cost approximately $150.00 per linear meter. The higher expense is due primarily to the cost of materials and labor required for the construction of the wooden forms necessary for the in-place fabrication of the concrete walls. Preformed concrete walls may be somewhat cheaper, but still not competitive with rock or gabion walls.

Other materials, such as redwood planks or railroad ties, may be used in the construction of breast walls or retaining structures. Use of these materials has not been evaluated at the project site. In the case of the railroad ties, a firm supply of these items was not found. In the case of redwood, the project staff did not believe the construction of retaining structures was an appropriate use of this limited resource.

Furthermore, the cost of the skilled carpentry labor required for the construction of these walls would have prohibited their construction using limited project funds. The cost of constructing a 0.9 meter redwood retaining wall is estimated to be approximately $45.00 per meter. Two-thirds of this cost ($30.00) would be for materials.

Breast Wall Effectiveness

Determining which type of slope toe stabilization method to employ is almost entirely dependent upon the cost of the particular structure. Any sound structure which provides dependable protection for the slope toe is sufficient. Porous walls, such as wooden walls, gabions, or ungrouted rock structures, are preferable. Such structures, if properly designed and constructed, will allow for the easy passage of surface water yet retain the eroding soil material. In a few cases at the Rubicon Properties project site, the interstitial spaces in the rock-wall structures were too large. These spaces allow for the passage of seepage water, but they also allowed soil to erode through the wall. Problems such as these can be prevented by careful construction practices.

Frequently, gabions are criticized as being unattractive "bird cages". It is argued that such "unsightly" structures should not be used for erosion control in highly visible areas, such as adjacent to roadways. Indeed, if large rocks are readily accessible, inexpensive, and near to a proposed erosion control site, they should be used in the construction of large rock walls. If rock must be imported, it is likely that the cost of breast wall construction would be somewhat lower if gabions are used. Because of the high porosity of a filled gabion, soil can be placed in the gabion or will gradually filter into the voids. This will allow vegetation to establish itself on and around the gabion structure. The gabion structures used at the project site have not been in place a sufficient length of time to evaluate the success of establishing vegetation. Those areas where willows have been placed in and around the gabion structure, however, are expected to rapidly produce good vegetative growth and cover.

3. Slope Scaling and Overhang Removal

Proper slope scaling is a frequently neglected integral step in the stabilization of eroding cut and fill slopes. This is particularly true if the erosion control measures are installed some time after the original slope disturbance took place. If gullies, rocky areas, or other unstable sites are allowed to remain without proper treatment, the establishment of vegetative cover on an eroding slope will be considerably more difficult. It is far more cost-effective to adequately prepare an eroding slope prior to revegetation, than to come back time and time again to replant these disturbed areas. Figure VIII-27 shows a work force scaling an eroding cut slope.

Rocks pictured in Figure VIII-27 were subsequently used elsewhere to rock-line and stabilize an eroding drainage swale.

Slope scaling should be conducted after breast walls or other bench structures are formed at the toe of the slope. Exceptions are very large rocks or stumps which may require prior removal to avoid damaging the slope toe structure. The following is an example set of specifications which may be used to describe the scaling process:

Figure VIII-27. Scaling an eroding cut slope.

Scaling Process Specifications

a. All loose materials, exposed rock, and uneven surfaces shall be scaled and removed to the toe of the slope.

b. Precautions shall be taken to insure the safety of workers on steep slopes (2:1 or greater) by means of safety ropes and harnesses anchored securely to the top of the slope.

c. While removing large rocks from the slope, adequate precautions shall be taken to control their movement.

d. If the scaling is being conducted on a cut slope adjacent to or above a travelled roadway, the passage of traffic on the roadway adjacent to the section being scaled shall be restricted during periods when scaling is being conducted.

e. All scaled materials shall be immediately removed from the road surface and stockpiled at a site approved by the project engineer. In no case shall scaled material be placed within a gutter or drainage swale, nor shall it be placed on a road surface for longer than an 8-hour period.

f. Scaled material shall be stockpiled in locations not subject to concentrated runoff. Siltation berms and impervious coverings must be used to prevent erosion from the stockpiled area.

Overhangs, as defined in this report, are the excessively steep portions of eroding slopes, with slopes greater than 1:1, such as are frequently found at the crown of eroding cuts. When cut slopes are initially excavated, overhangs are usually non-existent. However, if the majority of a steeply cut slope remains unstabilized after initial excavations, the mid portion of a slope will generally erode more rapidly than the remainder of the slope. The erosion will continue until a slope angle equal to or less than the angle of internal friction of the soil has been achieved. The crown of the slope usually erodes more slowly than the mid-portion due to vegetation in undisturbed, natural terrain above the lip of the slope. Although the overhangs are more stable than the remainder of the slope, they will continue to erode, albeit more slowly. If plantings are placed on the lower portions of the slope without overhang removal, they may become buried or otherwise disturbed by material sloughed from the overhang. Furthermore, overhangs are frequently near vertical. Unless such areas are rounded and reduced in steepness, it is difficult, if not impossible, to establish plantings.

Overhang removal should also be conducted after construction of breast walls or other slope toe stabilization structures. Again the only exception is in the case of large stumps or boulders. Figure VIII-27 depicts a manual overhang removal operation. Over 95 percent of all overhangs at the Rubicon Properties and Northstar project sites were removed in this manner. Following is an example set of specifications which may be used.

Overhang Removal Specifications

a. Any overhang areas steeper than 1:1 (horizontal to vertical) at the slope crown shall be regraded and rounded to a maximum slope of 1.5:1.

b. All trees to be removed from the overhang area shall be clearly marked by the project engineer.

c. Soil removed from the overhang shall be placed behind the slope toe stabilization method (i.e., curb, breast wall, retaining structure) employed at the toe of the slope.

Scaling and Overhang Removal Costs

At the Rubicon Properties project site, approximately 300 cubic meters of overhang material were removed and placed as fill behind breast walls and A-C dikes at the toe of eroding slopes. With the exceptions of the use of the loader for pulling trees and stumps and a backhoe for removing 51 cubic meters of overhang, all scaling and overhang removal were performed by manual labor. Manual removal of overhangs required about 2.5 hours per cubic meter of overhang. A current construction cost estimating handbook (51) indicates that loosening of earth by hand with a pick requires 2.0 - 4.0 hours per cubic yards (2.6 - 5.2 hrs. per cubic meter).

TABLE VIII-3

COMPARATIVE OVERHANG REMOVAL AND SCALING EQUIVALENT COSTS

ACTIVITY	UNIT COST ($/CUBIC METER)			
	MATERIALS	EQUIPMENT	LABOR	TOTAL
Manual scaling and overhang removal with aid of loader in removing stumps	---	1.91	40.77	42.68
Overhang removal with backhoe	---	2.13	4.87	7.00
Overhang removal with crane*	---	6.47	5.47	11.94

* Estimated rate of removal same as for backhoe.

Table VIII-3 illustrates the costs of overhang removal and scaling as experienced at the Rubicon Properties project site. Manual scaling and overhang removal is considerably more expensive than more mechanized methods employing heavy equipment such as backhoes and cranes. However, in many instances cut slopes are so long that it is difficult to find equipment with sufficient reach to allow removal of the overhang at the slope crown. Furthermore, the labor force used at the Rubicon Properties project site was so inexpensive that the unit cost of manual scaling and overhang removal was essentially equivalent to the unit cost of renting mechanized equipment to perform these tasks.

An additional cost of scaling and overhang removal is the cleanup of debris which may be deposited at the toe of the slope. At the Rubicon Properties project site, the average unit cost for debris cleanup on roadways adjacent to cut slopes was $4,086.00 per hectare of cut slope surface. Approximately 60 percent of this cost is for labor and 40 percent is for equipment needed to transport waste debris to an appropriate disposal site.

4. Contour Wattling

"Contour Wattling" was described by Kraebel (52) as early as 1936 in a USDA circular, but has seen little practical use in the United States outside of limited experimental applications. Kraebel defined "contour wattling" as "the packing of lengths of brush into continuous thick 'cables' partially buried across a slope at regular contour intervals and supported on the lower side by stakes". Experimental work on contour wattling prior to this report has been conducted by the Department of Environmental Horticulture, University of California, Davis, and the California Department of Transportation (CalTrans) as a means of controlling erosion on steep embankments adjacent to state highways in the Lake Tahoe Region of the Sierra Nevada. Contour wattling is particularly effective on slopes which approach, or are steeper than, the friction angles (angle of repose) of the local soil. Advantages of contour wattling are as follows:

1. The placement of wattling bundles into the eroding slope provides local stabilization to the upper .2 to .3 meter of soil surface. This prevents down slope movement of surface soil.

2. Contour wattling rows placed at repeated intervals effectively break a relatively long slope into a series of benched and shorter slopes. During heavy rains these repeated barriers prevent the formation of large gullies. Wattling rows act as effective miniature "percolation trenches" during a heavy runoff condition. This is particularly true if the contour wattling rows are left slightly exposed.

3. By keeping the soil in place, contour wattling allows the establishment of vegetation on a denuded slope. A slight bench is formed at each wattling row allowing for the germination and growth of seed material placed there either artificially or by natural processes. If the wattling bundles are made up of sprouting species, the rooting of the wattling itself will provide effective stabilization of the slope surface.

4. One of the best means of mechanically stabilizing steep slopes outside of ext nsive (and expensive) engineered retaining structures.

Contour Wattling Procedure

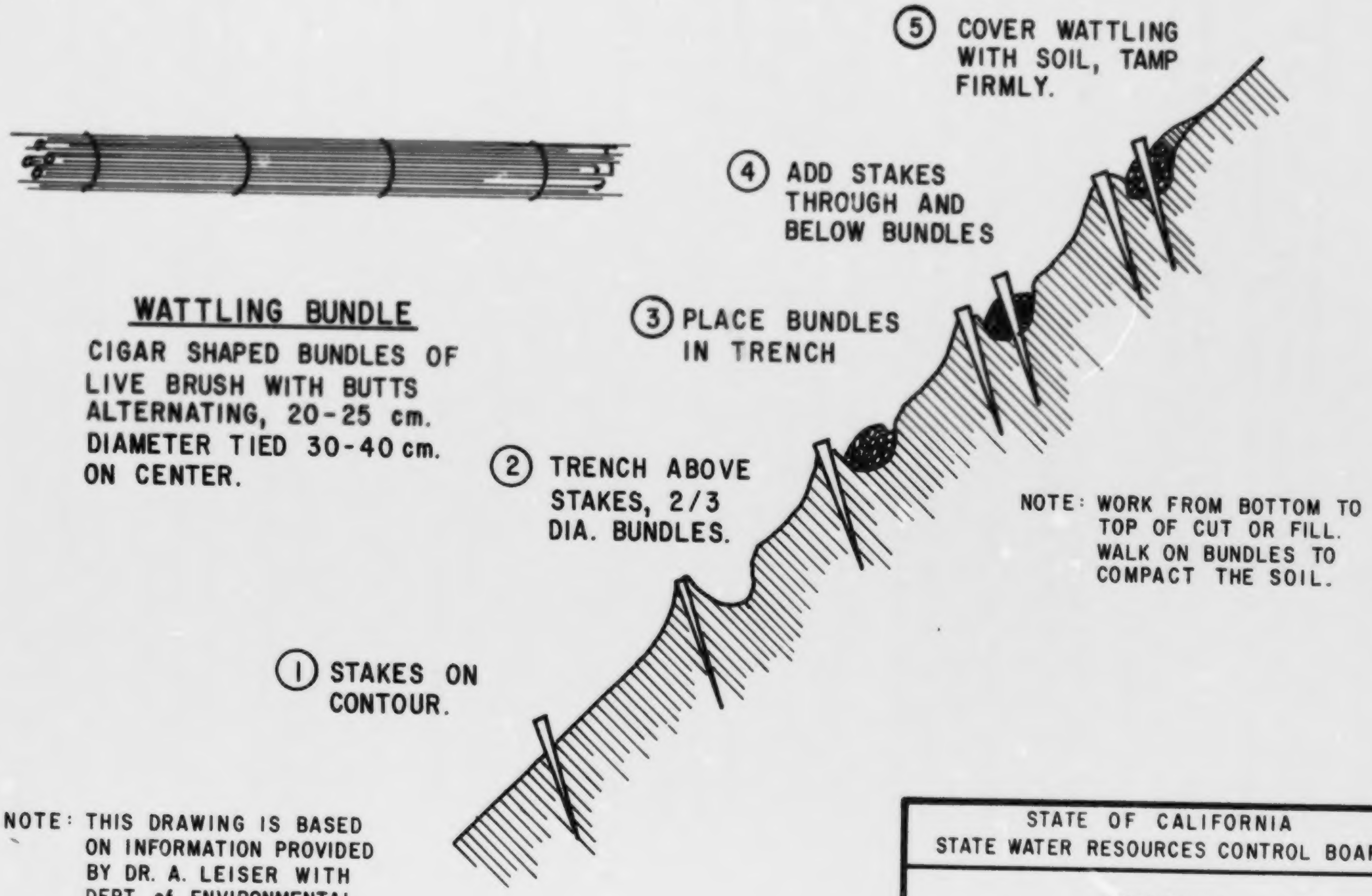
The following general procedure, adapted from Leiser (46), should be specified in the installation of contour wattling (see Figure VIII-28):

a. Wattling bundles shall be prepared from live shrubby material, preferably of species which will root, such as willows.

b. Wattling bundles may vary in length, depending upon material available. Bundles shall taper at the ends. Butts of stems shall be from 2 to 4 centimeters in diameter.

c. Stems shall be placed alternately in each bundle so that approximately one-half of the butt ends are at each end of the bundle.

d. When compressed firmly and tied, each bundle shall be 20 centimeters in diameter plus or minus 5 centimeters.


WATTLING BUNDLE
CIGAR SHAPED BUNDLES OF LIVE BRUSH WITH BUTTS ALTERNATING, 20-25 cm. DIAMETER TIED 30-40 cm. ON CENTER.
① STAKES ON CONTOUR.
② TRENCH ABOVE STAKES, 2/3 DIA. BUNDLES.
③ PLACE BUNDLES IN TRENCH
④ ADD STAKES THROUGH AND BELOW BUNDLES
⑤ COVER WATTLING WITH SOIL, TAMP FIRMLY.

NOTE: WORK FROM BOTTOM TO TOP OF CUT OR FILL. WALK ON BUNDLES TO COMPACT THE SOIL.

NOTE: THIS DRAWING IS BASED ON INFORMATION PROVIDED BY DR. A. LEISER WITH DEPT. of ENVIRONMENTAL HORTICULTURE at U.C. DAVIS.

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CONTOUR
WATTLING

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER
VIII-28

e. Bundles shall be tied on not more than 40 centimeter centers with two wraps of binder twine or heavier tying material with a non-slipping knot.

f. Bundles shall be prepared not more than one day in advance of placement except that if kept covered and wet they may be prepared up to seven days in advance of placement.

g. Grade for the wattling trenches shall be staked with a hand-held level, or similar device, and shall follow the horizontal slope contours.

h. Trenches shall be one meter vertical spacing or other as specified by the project engineer.

i. Bundles shall be laid in trenches dug to approximately one-half the diameter of the bundles with ends of bundles overlapping at least 30 centimeters. The bundles shall be as long as necessary to permit staking as specified below.

j. Bundles shall be staked firmly in place with vertical stakes on the downhill side of the wattling, not more than 0.5 meters on center and vertical stakes through the bundles on not more than 1.0 meter centers. Where bundle overlap occurs, an additional stake shall be used at the mid-point of the overlap. Bundle overlaps shall be tied with a vertical stake through the ends of both bundles.

k. Stakes shall be construction stakes (5 cm x 10 cm x 61 cm or 5 cm x 10 cm x 91.4 cm diagonal cut).

l. All stakes shall be driven to a firm hold and a minimum of 45 centimeters deep. Where soils are soft and 61 centimeter stakes are not solid (i.e., if they can be moved by hand) 91.4 centimeter stakes shall be used.

m. Work shall progress from the bottom of the cut or fill toward the top, and each row shall be covered with soil and packed firmly behind and on the uphill side of the wattling by tamping or by walking on the wattling as the work progresses, or by a combination of these methods.

n. The downhill "lip" of the wattling bundle may be left exposed when staking and covering are completed. However, step "m" must be rigorously adhered to.

Willows were the only plants used for contour wattling as part of this erosion control project, although other quick rooting and sprouting species may also be used.

The timing of willow cutting and cutting site selection can make a great difference in productivity of any willow wattling operation. When a variety of sites are available, the following criteria should be considered before making a final selection. First, try to schedule willow wattling for late fall or early spring, when willows are dormant or nearly dormant. Results at Rubicon Properties show markedly increased growth and survival of wattling cut and placed in May and September, over wattling cut and placed in June and July. Special handling, such as covering wattling with wet tarps during transport and frequent irrigation after placement may improve results of summer wattling. However, results at Rubicon Properties, even with this special handling were poor in comparison to early spring and late fall wattling. Second, the growth habit of the willow plant is important. Shoots, 2 - 3 meters long with few cross branches and few dead branches, are the most desirable. These branches form more uniform and easily tied bundles, and the plants' growth habitat is more open and easier to work in. Third, the willow cutting site must contain enough satisfactory wattling material to justify the time required to conduct the cutting operation. Generally speaking, if approximately 400 square meters of willow plants are available in a single area, the area is cost-effective to exploit. Fourth, the actual travel time to the cutting site is important. Cutting sites used as part of this erosion control project have ranged from 4 kilometers to as far away as 40 kilometers from the installation site. Substantially greater transportation distances would increase wattling costs considerably.

An adequately equipped and experienced five-person work crew should be able to cut, collect, and bundle one hundred 2.5 meter wattling bundles from one site in one 8-hour period. A production rate of two to three wattling bundles per person-hour may be reasonably expected. The only equipment required for the task of willow cutting and wattling bundling are: pruning shears, binder's twine, a sharp knife, a long bed half-ton pick up truck, a large tarp, and the necessary safety equipment, such as hard hats and gloves. A chain saw can be used to speed up the willow cutting operation, but is extremely hazardous and requires experienced personnel and additional safety equipment. An electric strapping tool requiring a portable generator was experimented with, but was found to be no more efficient than manually tied twine for tying the wattling bundles together. Furthermore, aesthetic and environmental objections might be raised over the use of nondegrading plastic strapping material.

Several tasks relating to wattling installation should be completed prior to the arrival of the wattling bundles at the project site. First, the alignment of the contour wattling rows must be determined. An initial stake is driven at the bottom of a slope face. From this point, stakes are placed at desired intervals up the slope face. Once this initial staking is completed, contour stakes are driven at approximate 6-meter intervals across the slope face along each contour, utilizing a hand held optical level. Finally, stakes are "eye-balled" in at 0.5 meter intervals along the contour.

The actual willow wattling installation must function as a dynamic process. Trenching, placing, staking, and burying of the willows must take place in rapid succession in order to minimize soil and plant moisture loss and maximize plant survival. Crew members should start trenching and preparing the ground, while others finish bundling the wattling and start placing them in the lowest trench. Once the lowest wattle is installed, the digging of the next higher trench may be started. This staggered trenching is important so that as the higher trenches are dug, sloughed soil falls into the lower trenches. If this process is operating properly, all material sloughed from above should land on installed wattling bundles.

Willows are installed so that approximately one-third of the bundle extends above the slope grade, enabling it to intercept overland runoff. For most willow bundles, 3 - 4 stakes driven through the bundle are sufficient to hold it in place. An additional stake is driven through the overlapping ends of adjacent bundles. A total of 3.5 construction stakes are required for every meter of contour wattling. The end wattling bundle should be angled up the slope to prevent any collected runoff from flowing around the end. The soil is then replaced and packed around the base of the wattling bundles. Again, this must be completed shortly after the willows are installed. The presence of adequate soil moisture adjacent to the bundles is imperative for plant survival. In an effort to provide ample soil moisture for willow growth and rooting at the Rubicon Properties and Northstar projects sites, all wattling installed at these sites was heavily soaked with irrigation water immediately after installation. In the case of mid-summer wattling plantings (July - August 1976) at Rubicon Properties, the willow wattled slopes

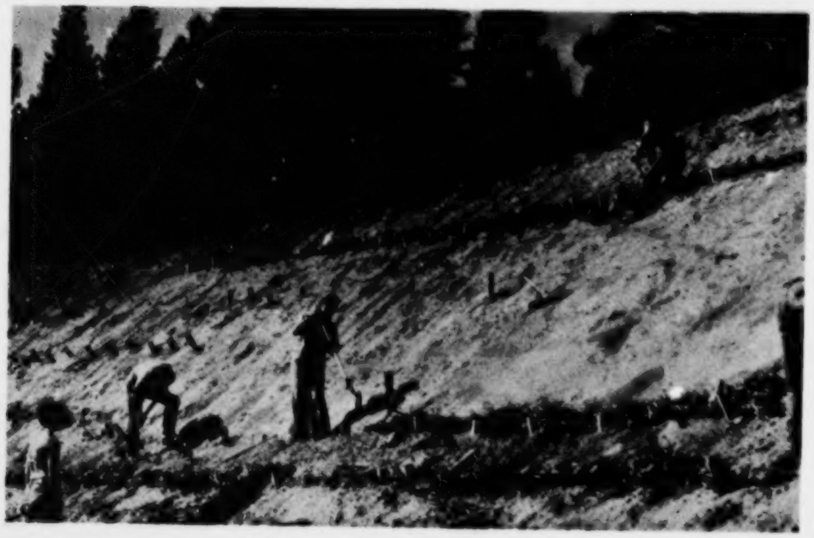


Figure VIII-29. Contour willow wattling installation at the Northstar erosion control project site.

were repeatedly soaked at no greater than one-week intervals throughout the summer. The rate of willow installation is limited primarily by the rate at which the trenches are prepared. When the contour wattling operation is functioning properly, approximately one hundred 2.5 meter wattling bundles may be stalled by a five-person crew in one day. Figure VIII-29 depicts a typical wattling installation in progress.

Contour Wattling Cost

By making the necessary arrangements and obtaining a permit from the U. S. Forest Service, willows may be harvested on Forest Service lands for the purpose of erosion control. It is therefore assumed that plant materials cost for willow wattling is negligible. The only substantial materials cost is for the construction stakes used to hold the wattling bundles in place. When purchased in large quantities, the unit cost is about $.25 per stake. Approximately 2,500 meters and 1,500 meters of willow wattling bundles were installed at the Rubicon Properties and Northstar project sites, respectively. At Rubicon Properties 238 person-hours were spent in the harvesting, and transporting 2,000 meters of willow materials 30 miles to the project site during the summer and fall of 1976. In addition, a total of 377 person-hours were spent in the bundling, staking, and burying of these bundles. The average spacing between wattling rows was 1.85 meters.

Equipment required for the willow wattling operation consists of a half-ton pick up truck, a chain saw, and assorted hand tools and safety equipment. Costs for the equipment is assumed to be $4.00 per hour for a five-person work crew. The willow wattling cost data is summarized as follows:

	$/meter
Materials	$0.88
Equipment	0.25
Labor	5.01
TOTAL	$6.14/meter

The total cost of $6.14 per meter for willow wattling is roughly equivalent to costs cited by Leiser (46) of $6.56 per meter. The cost summary shown above is based upon the cost assumptions used in this report as listed at the beginning of this appendix. Labor is assumed to cost $16.25 per hour.

Fully 82 percent of the cost of willow wattling is for labor. If less expensive labor is available contour wattling costs may be drastically reduced. At the Northstar and Rubicon Properties project sites, unskilled college students, Youth Conservation Corps workers (YCC) and California Conservation Corps workers (CCC), were used to install contour wattling. Based on an estimated cost of $5.00 per person-hour for wages, supervision, transportation, and minimum benefits, contour wattling installed by these groups cost approximately $2.67 per meter installed.

5. Other Methods

The methods for the mechanical stabilization of oversteepened slopes discussed previously in this section require revegetation of the slope to achieve the highest order of effective erosion control. There are, however, several other methods of mechanically stabilizing oversteepened slopes which do not require, nor depend upon, revegetation to effectively control erosion. The wide variety of products and techniques available to achieve non-vegetative oriented control are too numerous to mention in any detail. A few representative techniques will be briefly touched upon in this section. None of these approaches were demonstrated at either the Northstar or Rubicon Properties erosion control project sites; they were excluded by the following selection criteria:

- the judgement that they were aesthetically unpleasing in comparison to vegetation, and
- the cost of materials and installation which absolutely prohibited their use as part of this project.

Examples of this "non-revegetative" approach to mechanical stabilization of oversteepened slopes include gabion revetments, concrete anti-erosion grid revetments and gunite revetments. A revetment, as used in this text, means an artificial structure devised to cause earth to stand at a steeper slope than it would naturally assume.

Gabion Revetments

Wire mesh gabions may be used to form breast walls and retaining structures at the toe of a steeply eroding slope as discussed in a previous section. These devices may also be used to completely cover an eroding slope in the form of a revetment. In order to place rocks in gabion revetments, extensive heavy equipment such as a loader and/or crane with a bucket attachment is required. Wire mesh gabion baskets may be obtained in a variety of thicknesses to form a revetment structure.

Gabion revetment structures do have the advantage of being relatively easily revegetated. Soil placed in the interstices of the rock fill can support vegetation. Once the movement of soil from the slope is stabilized by the use of a gabion revetment, the natural invasion of native plants may be expected to occur much more readily. The porous nature of the gabion revetment also allows easy passage of seepage water that may occur naturally on the slope. Because of their great flexibility, gabion revetments cannot crack or otherwise lose their structural integrity even if considerable shifting or settling occurs.

Concrete Anti-Erosion Grid Revetments

A variety of these concrete anti-erosion grids are currently available. One type of concrete grid is precast, slotted, .25 square meter blocks. The manufacturer indicates that these blocks may be placed on slopes up to a 1:1 angle. Similar to a gabion revetment, the perforations in the grids would facilitate the establishment of vegetation. One apparent

TABLE VIII-4

ESTIMATED REVETMENT COST FOR
STABILIZATION OF OVERSTEEPENED SLOPES

REVETMENT	UNIT COST ($/SQUARE METER) MATERIALS	EQUIPMENT	LABOR	TOTAL
Gabion Revetments	$12.50	$4.16	$11.12	$27.78
Concrete Anti-erosion Grids	12.84	---	11.83	24.67
Gunite Revetments	5.05	2.86	2.86	10.76

disadvantage is the absolute inflexibility of the individual blocks. A slope where the grids are used must be completely level prior to installation, an added disadvantage of the grids is their high unit weight. One type of grid weighs 42 kilograms per block. Unlike gabions, which may be filled by means of heavy equipment, anti-erosion grids must be placed individually with manual labor. Other applications of this particular type of product are many and varied. One application which should receive further evaluation in the Tahoe-Sierra region of California is their use as pervious paving surfaces for parking lots. Because of their slotted perforations, concrete anti-erosion grids should be able to reduce or eliminate storm water runoff from otherwise impervious surfaces and thereby lessen the need for extensive storm water infiltration works.

Gunite Revetments

Gunite is sprayed concrete applied directly to a subject by means of an air jet. A mechanical feeder, mixer, and compressor comprise the principal equipment for this method of placement. Gunite can be effectively pplied to near vertical slopes and is usually applied to a depth of about 10 centimeters. Disadvantages include gunite's rigid and non-porous structure. Gunite may be subject to cracking or chipping if any settlement or shifting occurs. Because of gunite's non-porous nature, extensive seepage lines or "weep-holes" must be placed on gunited slopes to prevent the buildup of hydrostatic pressure which could lead to the failure of the gunite revetment. Use of gunite will increase the amount of storm runoff from a particular area. If its use leads to extensive runoff and off-site erosion problems, use of gunite should be discouraged. Furthermore, objections may be made regarding the use of gunite due to its unnatural appearance.

Due to the above problems encountered with the use of gunite, its use should be limited to only special problem areas. One type of problem for which gunite may be useful is the control of erosion from steep, near vertical decomposing granite construction cuts. Vegetation is next to impossible to establish in such locations and the existing decomposing granitic rock is already highly impervious.

Revetment Costs

The slope treatments mentioned above are considerably more expensive than revegetative erosion control measures. For this reason alone, use of revetment structures should be limited to special situations and extreme problem areas where other methods are unlikely to succeed.

Table VIII-4 summarizes the estimated costs of the above discussed revetment structures. Cost data is derived solely from manufacturers' and/or contractors' estimates. The actual unit costs may vary depending on transportation, site accessibility, labor costs, and area covered. The values given in Table VIII-4 are rough estimates for comparative purposes only.

F. Permanent Vegetative Erosion Control

Erosion control methods described in this section are treated by this report as the best approach to the permanent control of erosion from disturbed areas. Effective revegetation will increase the abstraction and permeability of the disturbed area and reduce the impact which storm water runoff may have on down gradient areas. Furthermore, once established, vegetation requires a minimum amount of maintenance, particularly if native plants are able to "reinvade" a previously disturbed area. Achieving satisfactory establishment of vegetation is dependent on climatic conditions. Unless irrigation is provided, revegetation should only be conducted in the Tahoe-Sierra region in the fall or preferably the early spring.

The possible need for "follow-up" plantings and seedings must be acknowledged. In most situations, follow up seedings are relatively inexpensive (less expensive than providing irrigation) and can easily be provided for. If a fall seeding does not establish satisfactory growth due to frost heaving or other causes, additional seedings should be conducted in the following spring. In all cases, vegetative erosion control in the Tahoe-Sierra, albeit relatively inexpensive, is a somewhat speculative venture.

On gentle slopes (2:1 or less), the vegetative techniques described herein, singly or in various combinations, should be effective in controlling erosion from these disturbed areas. However, on steeper disturbed terrain, or in situations where drainage control is poor, slope stabilization and proper drainage control prior to revegetation is essential to successful establishment of plants. At the Northstar and Rubicon Properties erosion control sites, the use of contour willow wattling, for example, has more than doubled the survival of other plants.

A wide variety of revegetative techniques are discussed in this section, ranging in expense from less than $.10 per square meter for seeding and mulching to over $2.00 per square meter for native plantings or manual installation of various mulch nettings and blankets. However, in many instances, a considerable commitment of funds is required for mechanical slope stabilization prior to revegetation. The unit erosion control cost for slopes that require massive slope stabilization in the form of retaining walls frequently exceed $20.00 per square meter of slope face. As eroding slopes become steeper and longer, the vegetative portion of effective erosion control represents only a small portion of the total cost.

This section on vegetative erosion control will deal with the following subject areas:

- willow staking
- container and bare root plants
- seed and fertilizer
- seeding and mulching techniques
- fiberglass roving

All of the above planting techniques, with the exception of fiberglass roving, were used extensively at either the Northstar or Rubicon Properties erosion control project sites. The discussion of seeding and mulching techniques is particularly extensive and includes hydromulching, straw mulching, straw tackifying, and mulch nets and blankets.

1. Cut Willow Stakes

Planting a slope with cut willow stake cuttings can be an effective method of providing a quick, cheap method of revegetating eroding slopes. Other plants such as dogwood (Cornus) and alder (Alnus) may also be satisfactory for this purpose but were not tried on these projects. Willow staking has been conducted with considerable success even on relatively dry, south facing, exposed slopes. The best results with willow staking are achieved if the following procedure is rigorously adhered to.

Willow Staking Procedure

Plant materials are gathered in much the same manner as for the contour wattling operation. Sources of willow are readily available in the Lake Tahoe Basin by gaining a use permit for removal from Forest Service lands. Willow shoots may be cut by either pruning shears or a chain saw. Small branches should be trimmed from the willow shoots ranging from 1 to 2.5 centimeters in diameter. The shoots are cut into 15 to 45 centimeter lengths using either a hand axe or a circular saw and marked with spray paint at their basal ends. The cut length of the willow stakes is dependent upon the ease with which they may be driven into the ground. The stakes should be as long as possible, up to 45 centimeters, with no more than 2 - 4 centimeters exposed above the slope surface once they are driven in place. The longer the stake, the better chance it has for survival.

Figure VIII-30. New growth on a successfully planted willow stake.

TABLE VIII-5

WILLOW STAKING EQUIVALENT COST

	TIME hr/stake	EQUIVALENT COST $/stake
Materials	(No materials other than willows are required.)	
Equipment	.007	.028
Labor*		
- harvesting	.008	.130
- cutting	.010	.163
- installation	.009	.141
TOTAL	.027	.462

*Note: Equivalent labor cost is assumed to be $16.25 per person-hour.

On unconsolidated decomposed granitic soils, willow stakes may be placed with relative ease at any time. On harder soils with higher clay content, use of a star drill or other devices may be required to make planting holes. Due to the very dry summertime conditions in the Sierra Nevada, willow staking should be conducted in either the early spring or late fall to be assured of adequate soil moisture to support growth. In most instances the rate of successful plant growth from willow staking appears to be much greater than from willow wattling. As is true with contour wattling, willow stakes should be cut immediately prior to installation, and never stored for longer than a 12-hour period unless they are kept cool and moist. Willow branches for stakes may be stored up to 7 days if properly stored. A successfully planted willow stake is pictured in Figure VIII-30.

Willow Staking Cost

Equipment required for the willow staking process includes a half-ton pick-up truck, chain saw, and assorted hand tools. The cost of this equipment is assumed to be $4.00 per hour for a five-person work crew. The willow staking cost data, as performed at Northstar, is presented in Table VIII-5. Willow stakes were placed at a density of about four per square meter.

2. Plants

Reestablishment of native plants is generally held to be ideal revegetative approach for erosion control. Reasons for this include:

1. aesthetically pleasing control method, blending in with the surrounding natural environment
2. lower fertilizer requirements for native species
3. lower water requirements for native, drought tolerant species

Difficulties which are encountered with revegetation using native species include:

1. plants are not generally available except by advance contracts with growers
2. plants are relatively expensive due to difficulties of propagation and cultivation resulting in greater risks to growers
3. poor survival of small seedlings and cuttings when given a minimum amount of attention and care
4. frequently provide less than adequate ground cover for effective soil stabilization and erosion control

Considerable work has been recently conducted by the Department of Environmental Horticulture, University of California, Davis, in propagation of native Sierran plants for erosion control and revegetation. Propagation methods for such plants are covered in detail in Appendix A.

Plants received at the erosion control project sites came in a variety of containers:

1. Shrubs - rooted cuttings and seedlings,
    - 7.5 cm. peat pots
    - 15 cm. and 25 cm. PVC deep conical tubes
    - 13 cm. and 25 cm. thin ployethylene book planters
2. Bare root tree seedlings,
    - bundles of 50
3. Grass seedlings,
    - 7.5 cm. peat pots

The principal plants used as part of this erosion control demonstration project are as follows (for a complete listing, refer to Appendix A):

1. Shrubs
    - a. *Arctostaphylos patula* (greenleaf manzanita)
    - b. *Arctostaphylos nevadensis* (pinemat manzanita)
    - c. *Artemesia tridentata* (big sage)
    - d. *Ceanothus prostratus* (squaw carpet)
    - e. *Purshia tridentata* (bitterbrush)
    - f. *Penstemon newberryi* (mountain pride)
    - g. Various *Lupinus* species (lupines)
    - h. Various *Salix* species (willow)
    - i. *Prunus emarginata* (bitter cherry)
    - j. *Atriplex canescens* (salt bush)
    - k. *Chrysothamnus nauseosus* (rabbitbrush)
2. Bare root tree seedlings
    - a. *Pinus jeffreyi* (jeffrey pine)
    - b. *Pinus lambertiana* (sugar pine)
    - c. *Abies magnifica* (red fir)
    - d. *Abies concolor* (white fir)
3. Grass
    - a. Various rhizominous wheatgrasses.

Judging from early results, the best success has been achieved by *Purshia tridentata*, *Artemesia tridentata*, *Penstemon newberryi*, *Atriplex canescens*, *Pinus jeffreyi*, *Chrysothamnus nauseosus*, and the grass clones.

Planting Procedure

Once plants have been transported to the erosion control site, they should be acclimated for approximately 1 - 2 weeks. During this period, plants should be watered only when necessary, with a final watering just before planting. Bare root seedlings should be delivered to the erosion project site in the early spring and planted as soon as possible. Those seedlings not used immediately should remain boxed in a cool, dark place and thoroughly doused with water daily.

At the project site, the actual planting operation requires three or more people. Two or more individuals are involved with placing the plants in the ground, while at least one individual is responsible for supplying each "planter" with plants as needed. On less severely sloping sites, each "planter" may be responsible for providing his/her own supply of plants. Planting should proceed from the top of the slope to the bottom at staggered intervals along the contours of the slope face. This prevents soil disturbed by foot traffic from being sloughed and deposited on plants lower on the slope. Each "planter" is responsible for the following planting procedure (see Figure VIII-31):

1. On a loose sloughing slope (such as decomposed granite), dig a hole just large enough for the root ball of the plant.

   On consolidated slopes, the above procedure may be followed, or dig a shallow bowl shaped excavation and form a slight brim on the downhill side. An additional excavation large enough to contain the root ball of the plant is made in the low point of the bowl, normal to the surface. The purpose of the bowl is to allow surface irrigation and to trap rainwater. Care must be taken to remove all loose soil around the bowl which may erode into the bowl and bury the plant.

   An additional excavation made to the dimension of the plant container is made in the low point of the bowl normal to the surface.

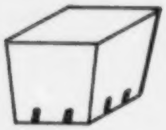
2. The plant and potting material is removed from the container and placed in the excavated hole. (In the case of peat pots, the plant and potting material are not removed. However, any portion of the peat pot extending above the potting material surface must be removed. This prevents a loss of soil moisture from around the roots of the plant via a "wick effect".)

3. The top surface of the root ball should be at or slightly below the level of the surrounding soil.

4. The native soil is compacted around the plant. Once the plant is in place, those having basin areas should receive about 2 liters of water.

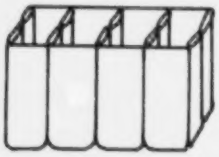
In the case of bare root seedlings, essentially the same procedure is followed with the exception that the hole in which the seedling is placed

PROPER PLANTING OF CONTAINER PLANTS



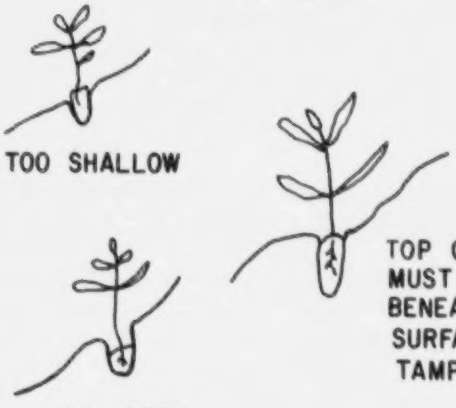
PEAT POT - BREAK OFF RIM OF POT ABOVE SOIL LINE PRIOR TO PLANTING.

DEEP TUBE - TO REMOVE PLANTS, INSERT CONTAINER AND KNOCK RIM AGAINST A ROCK OR SHOVEL. PROTECT PLANT FROM INJURY.



BOOK PLANTERS - PLANTS ARE GENTLY REMOVED AFTER OPENING THE BOOK. PLANTERS ARE FRAGILE, BUT REUSEABLE.

PLANTING


TOO SHALLOW
TOP OF ROOTS MUST BE JUST BENEATH SOIL SURFACE. TAMP FIRMLY.
TOO DEEP

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

CONTAINER
PLANTS

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER
VIII-31

must be sized to accept the full root system. The planter should be careful not to compress the root system against the central stalks as soil is replaced around the plant.

Fertilizer is not required when planting the bare root or contained shrubs. The grasses require about one gram of 16-20-0 fertilizer placed at the bottom of each hole. Care should be taken to mix fertilizer into the soil at the bottom of the hole to avoid burning the plants. If planted early in the spring or fall, the plants should not require continuous watering. However, greater success can be assured if water is available when the plant is initially placed in the ground and for subsequent watering until the plant is established. Once the root system of a native drought-tolerant plant is well established (1 - 2 months), further artificial watering should not be necessary.

Planting Costs

Plants for erosion control may be obtained from commercial growers if substantial (½-1½ year) advance notice can be given (see Appendix A). Native shrubs vary widely in costs. If large quantities (1,000 or greater) of plant materials in 7.5-centimeter peat pots, or equivalent size, are ordered in advance, the cost per plant may be as low as $.50 per delivered plant for the more common species. Bare root tree seedlings acquired from the California State Division of Forestry plant nurseries can be obtained for as little as $.05 per plant including transportation. Although data is not readily available, it is likely that grass seedlings in 7.5-centimeter peat pots may be obtained for as little as $.10 per peat pot. For more detailed information on plant propagation costs refer to Appendix A.

Over 20,000 plants were planted at Rubicon Properties in the fall of 1976 and spring of 1977. Individual planting rates varied from 20 plants per hour to over 50 plants per hour. With reasonably good conditions (i.e., moderate slopes and cool weather), sustainable rates of about 40 plants per hour for shallow containers and 30 plants per hour for bare root trees (large root systems) might be expected.

Equipment required for planting operations involve, at a minimum, a half-ton pick-up truck and various hand tools. The hourly equipment cost is about $3.50 per hour for a five-person work crew. Plants at the Rubicon Properties project site, at an average, were placed 2 - 4 plants per square meter. The planting unit cost data is summarized in Table VIII-6.

3. Seed and Fertilizer

The ideal objective of revegetative erosion control is to ultimately produce a vegetative cover which is native and blends naturally with the surroundings. Most erosion control seed mixtures contain nonnative grasses with the fertilizer added separately. Legumes, native shrub, and wildflower seeds, may also be added. The primary role of the nonnative fertilized grass seeding is to provide a quick, temporary (1 - 5

TABLE VIII-6

EQUIVALENT COSTS OF PLANTS FOR EROSION CONTROL

	UNIT COST ($/PLANT)			
PLANT TYPE	MATERIALS	EQUIPMENT	LABOR*	TOTAL
Shrubs	.500	.047	.406	.954
Bare Root Seedlings	.050	.035	.542	.627
Grass Plant Clones	.100	.047	.406	.554

*Note: Equivalent labor cost is assumed to be $16.25 per person-hour.

years) means to stabilize eroding soil. This allows development of slow growing, less nutrient-dependent native species, which otherwise would have been unable to gain a "foothold".

A wide variety of seed and fertilizer is available for erosion control plantings. The seed and fertilizer used for this erosion control demonstration project are shown in Table VIII-7. The individual species which were chosen for use were based upon the success of previous seedings conducted in the Lake Tahoe-Sierra Nevada environment (46, 53, 54). Those species listed in Table VIII-7 are described below.

Grasses

'Luna' pubescent wheatgrass (Agropyron trichophorum 'Luna'). 'Luna' pubescent wheatgrass shows more seedling vigor than the other grasses and, except for 'Tegmar' or 'Oahe' intermediate wheatgrasses, has established better on droughty or otherwise difficult sites. 'Luna' is rhizomatous and matures early (at about 60 centimeters).

'Tegmar' intermediate wheatgrass (Agropyron intermedium 'Tegmar'). 'Tegmar' intermediate wheatgrass is slightly inferior to 'Luna' pubescent wheatgrass in establishment but superior to other intermediate wheatgrasses. It could be substituted for 'Luna' pubescent wheatgrass. 'Tegmar' intermediate wheatgrass is rhizomatous, stays green longer, and is shorter than 'Luna'.

'Durar' hard fescue (Festuca ovina duriuscula). 'Durar' hard fescue is a non-rhizomatous short grass.

'Potomac' orchard grass (Dactylis glomerata 'Potomac'). 'Potomac' orchard grass is a fast growing, non-rhizomatous, short grass.

'Manchar' smooth brome (Bromus inermis 'Manchar'). 'Manchar' smooth brome, a rhizomatous grass, has deep green foliage and broad brown seedheads which add color and contrast to mixtures with the above grasses.

'Lincoln' smooth brome (Bromus inermis 'Lincoln'). 'Lincoln' smooth brome is rhizomatous, and is similar to 'Manchar' described above.

'Luna' and 'Tegmar' wheatgrasses may be difficult to obtain commercially. Orders for these species should be placed well in advance. If necessary, more available rhizomatous substitutes include 'Oahe' intermediate wheatgrass, 'Topar' pubescent wheatgrass, and western wheatgrass. Rhizomatous species are highly recommended due to their ability to extend and increase the percentage of plant coverage from year to year on difficult sites where species relying solely on seed production face severe limitations.

Other nonrhizomatous, fast growing species such as 'Potomac' orchard grass provide rapid stabilization of problem sites until other species have an opportunity to become established.

Grass seed mixture application rates used as part of the erosion control demonstration project have ranged from 40 to 86 kg/hectare. A rate of 40 kg/hectare should be sufficient if the seed is incorporated into the soil and then mulched. However, a rate of 80 kg/hectare or higher is recommended if the seed is placed on the soil surface or applied with the mulch. The "best" results at the Northstar project site were achieved with a hydromulched plot which was accidentally seeded at a rate of 260 kg/hectare!

Legumes

'Lutana' cicer milkvetch (Astragulus cicer 'Lutana'). Cicer milkvetch is a rhizomatous spreading legume which develops slowly but can grow up to 50 centimeters in height.

'Dutch' white clover (Trifolium repens). 'Dutch' white clover is a low growing rhizomatous legume.

'Cascade' Trefoil (Lotus corniculatus 'Cascade'). 'Cascade' Trefoil is a bushy legume reaching heights of up to 60 centimeters and produces a colorful yellow flower.

Legumes provide some nitrogen to other plants, such as the grasses, which would otherwise require continuous fertilization on the more sterile sites. In many instances, legumes are difficult to grow at higher elevations and at dry sites. All legumes planted from seed require inoculation with the proper Rhizobium bacteria. If legume seeding is specified using a hydraulic system, the legume seeds should be pellet-inoculated (22).

Legume seed mixture application rates used as part of the erosion control demonstration project have ranged from 12 to 25 kg/hectare.

TABLE VIII-7

PERCENTAGE COMPOSITION OF SEED AND FERTILIZER MIXTURES USED AT THE EROSION CONTROL PROJECT SITES

	Grass Seed Mixtures			
GRASSES	A	B	C	D
Luna pubescent wheatgrass	11	11	16	40
Tegmar intermediate wheatgrass	66	56	42	40
Durar hard fescue	17	--	16	--
Potomac orchard grass	--	33	16	20
Manchar smooth brome	6	--	--	--
Lincoln smooth brome	--	--	10	--
	100	100	100	100

	Legume Seed Mixtures			
LEGUMES	A	B	C	D
Lutana cicer milkvetch	57	50	67	50
Dutch white clover	24	50	11	50
Cascade trefoil	19	--	22	--
	100	100	100	100

	Shrub Seed Mixtures		
SHRUBS AND WILDFLOWERS	A	B	C
Artemisia tridentata	10	100	100
Purshia tridentata	30	---	---
Oenotheria hookeri	20	---	---
Linum lewisii	10	---	---
Gilia leptantha	10	---	---
Nemophila maculata	10	---	---
Eschcholzia calif.	10	---	---
	100	100	100

	Fertilizer Mixtures		
FERTILIZERS	X	Y	Z
16-20-0 (fast)	100	45	--
7-40-6 (slow-pellet)	---	55	--
38-0-0 (slow-pellet)	---	--	40
0-20-0 (fast)	---	--	60
	100	100	100

Shrubs and Wildflowers

'Basin Sagebrush' (Artemesia tridentata). 'Basin Sagebrush' is a common drought tolerant shrub found in desert and mountainous regions of the west.

'Bitterbrush' (Purshia tridentata). 'Bitterbrush' is a drought tolerant shrub with bright yellow flowers, common to the eastern slope of the Sierra Nevada range.

'Hooker's Evening Primrose' (Oenotheria hookeri). 'Hooker's' Primrose is a wildflower with large yellow petal usually found in moist areas below 2,000 meters elevation.

'Western Blue Flax' (Linus perenne lewisii). 'Western Blue Flax' is a wildflower with light blue petals, usually found in dry, open exposures up to 4,000 meter elevations.

'Showy Blue Gilia' (Gilia leptantha ssp. purpusii). 'Showy Blue Gilia' is a wildflower with pinkish violet flowers, usually found in moist open exposures up to 2,500-meter elevation in the southern Sierra Nevada.

'Fivespot' (Nemophila maculata). 'Fivespot' is a sprawling wildflower with white flowers having large purple spots, usually found in moist areas of the western Sierra Nevada range below 2,500-meter elevations.

'California Poppy' (Eschscholzia californica). The 'California Poppy', the California state flower, is a wildflower with bright orange to yellow petals, common in open, dry places below 2,500-meter elevations.

Several other species of shrubs and wildflowers native to the Sierra Nevada range are also available commercially. Sage and bitterbrush were chosen because of their drought tolerance. The various colorful wildflowers were chosen more for aesthetic reasons than as a practical means to control erosion. Prior to the erosion control demonstration project, little work has been done demonstrating the feasibility of establishing these types of plants at such severe sites as are found within the demonstration project sites. The California poppy has shown the greatest promise as a colorful additive to difficult erosion control sites.

Shrub and wildflower mixture application rates used as part of this demonstration project have ranged from .2 to 4.5 kg/hectare.

Fertilizers

16-20-0. The 16-20-0 fertilizer used was a fast release fertilizer which dissolves rapidly in water. It has a good balance of nitrogen, phosphorus, and sulfur. All three are deficient for herbaceous vegetation in the vicinity of Lake Tahoe (46).

7-40-6. The 7-40-6 fertilizer used, Mag Amp, was a slow release fertilizer in pellets (approximately one centimeter in diameter) which dissolve very slowly in water. The large pellets can clog a hydroseeder and lead to higher application costs. It contains no sulfur.

38-0-0. The 38-0-0 fertilizer, or urea formaldehyde, was a slow released fertilizer in pellets (approximately 0.3 centimeter in diameter) which is broken down slowly in the soil. It contains only nitrogen.

0-20-0. The 0-20-0 fertilizer, or single super phosphate, is a fast release fertilizer, containing phosphorus and sulfur, used to supplement the urea formaldehyde.

There is a considerable degree of controversy surrounding the use of fertilizer, particularly within the Lake Tahoe Basin. Overfertilization creates a potential for the fertilizer to enter surface waters by means of storm-water runoff. Fast release fertilizer, such as 16-20-0, is of greatest concern due to its solubility. The level of fast release fertilizer use, as part of the erosion control demonstration project, has been held to about 280 kg/hectare of 16-20-0. The levels of fertilization used at the erosion control demonstration site contains approximately one-tenth the nitrogen which is normally applied to a typical golf course in a single season. A rate of 280 kg/hectare for 16-20-0 is one-half the minimum rate normally recommended for erosion control seedings elsewhere in California (55).

Even at 280 kg/ha, if a 2.5 centimeters per hour rainstorm were to wash away all the 16-20-0 fertilizer applied to one hectare, the result would be 250,000 liters of runoff with a nitrogen concentration of approximately 180 mg/l. The California Regional Water Quality Control Board, Lahontan Region, has estabished a .20 mg/l total nitrogen water quality objective for Lonely Gulch Creek, a creek receiving runoff from the Rubicon Properties project site. A discharge of 250,000 liters of water with a total nitrogen concentration of 180 mg/l would be a clear violation of this water quality objective. If any more nitrogen than 1/1,000 of that applied as fertilizer were to be carried in 2.5 centimeters of runoff water, there would probably be a violation of water quality objectives for Lonely Gulch Creek.

Fortunately, the limited monitoring conducted thus far at the erosion control project sites has not indicated any increase in nitrogen concentration which could be attributed to erosion control fertilization, possibly because much of the fertilizer is bound to the soil particles. Well designed erosion control measures prevent any significant overland flow which could wash fertilizers or soil particles into surface waters. Well stabilized soil with incorporated nutrient materials will not be easily eroded or deposited in surface water drainages.

On a few plots, slow release fertilizer (7-40-6) was applied at a rate of 280 kg/hectare along with the fast release fertilizer (16-20-0) at 280 kg/hectare. The success of the slow release fertilizer in sustaining long-term growth of the seeded plant species is not ascertainable at this time.

In most instances, limiting fertilization to slow release fertilizers would not provide nutrients to the plant when most needed, immediately after germination. Use of a slow release fertilizer should be combined with a faster release type. If inexpensive labor or equipment is available, the best approach to fertilization of seeded erosion control sites is to conduct low level applications of fast release fertilizers on an "as needed" basis. This is likely to be the least expensive, least polluting, and best plant growth practice.

High fertilization rates may be detrimental to the growth and development of native plant species in and around the Tahoe Basin. Many native plant species have developed abilities to survive in nutrient deficient environments. These native plants have difficulty competing with artificially fertilized nonnatives. Figure VIII-32 shows an area of a topsoiled roadcut at the Northstar project site. The native manzanita shrubs (Arctostophylos patula) seen in the photo developed from seeds contained naturally in the topsoil. The grasses seen in the right half of the picture are the results of a hydromulched grass seeding experimental plot on a portion of the topsoiled area. In the portion of the topsoiled area which was hydromulched, seeded, and fertilized, there is less than 50 percent of the manzanita growth which is occurring in the "topsoiled-only" portion on the left. The picture was taken in 1977, six years after the topsoiling and four years after the grass seeding.

Seed Placement

Four basic methods for the placement of seed and fertilizer were used as part of the erosion control demonstration project. These included:

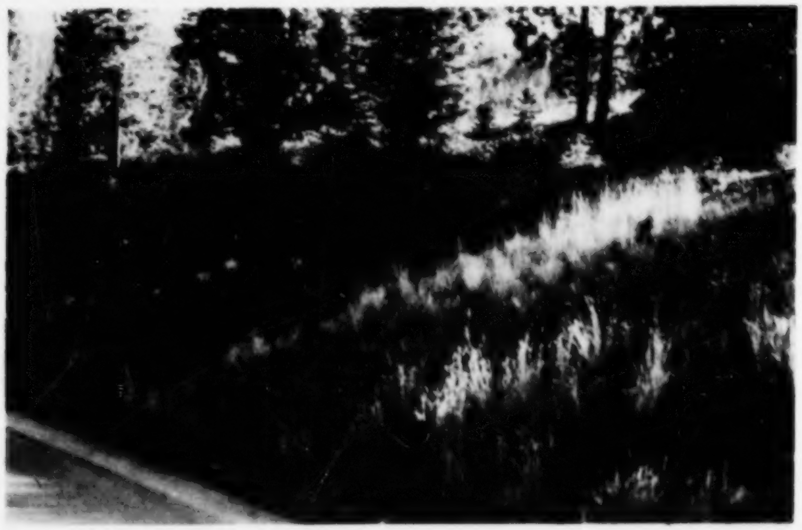


Figure VIII-32. Competition between artificially seeded plant materials and native shrubs on a top-soiled slope at Northstar.

1. "drilling" on a level site by means of a range drill
2. manual application of seed and fertilizer, followed by manual raking prior to a mulch application
3. hydraulic seeding and fertilization with hydroseeding equipment prior to an application of mulch
4. application of seed, fertilizer, and mulch conjunctively in a one-step hydromulching operation

The highest germination percentage and the best results are obtained when the seeds are covered with soil. This may be achieved on level surfaces by use of a range drill, as shown in Figure VIII-33, or a similar device. On steeper sites, or if a drill is not available, seeding may be done by manually broadcasting, then lightly raked or buried by dragging a chain over the seeded area. Grass seeds should never be covered more than one centimeter, except on decomposed granite where they may be covered to a depth of 2 to 3 centimeters. Once the seed is in place, the ground surface should be mulched. Best results may be expected from this method.

If hydroseeding equipment is available, the seed may be hydraulically applied to the soil surface in a water slurry with 20 metric tons of mulch/hectare for visual metering and seed cushioning. An application of mulch over the hydraulically seeded slope is then required.

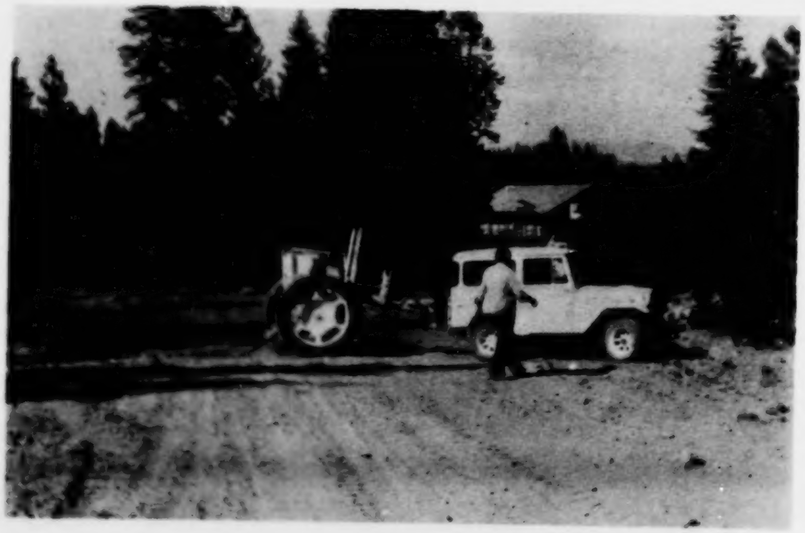


Figure VIII-33. Seed and fertilizer placement on a level unvegetated area by means of a range drill.

If an economical and efficient operation is required, the mulch, seed, and fertilizer may be hydraulically applied in a one-step operation. For a more complete discussion of hydroseeding and seed application in mulch, see the section on hydromulching. Generally poorer results are obtained using this method due to the fact that a large percentage of the applied seed is suspended in the mulch and not in contact with the soil.

The consequences of foot traffic or other disturbances on a seeded slope is somewhat inconclusive. In some instances, foot traffic on a seeded slope appears to enhance survival by incorporating the seed into the soil. In other instances foot traffic on steeper areas, particularly those with exposed hardpan outcrops, can dislodge the seed and cause it to be sloughed to the toe of the slope.

Irrigation. Repeated irrigation of a seeded area will enhance seed germination and plant survival. If irrigation facilities are not available, seeding should only be conducted in the early spring or late fall just prior to the appearance of snow. Without a backup irrigation system, a seeded slope is at the mercy of the weather. If an irrigation system is available, the water must be applied very slowly to guard against erosion induced by runoff. The seedbed must be kept continuously wet until the seeds sprout.

An irrigation system which could deliver 2.5 centimeters of water to a 1.0 hectare seeded area once every two weeks at a rate of .5 centimeter per hour would cost approximately $3,000 per hectare for installation. An additional expenditure of approximately $1,000 per month the installation costs ($1,500) involves materials which would be reuseable elsewhere. Assuming that irrigation would be required for two months (a total of 10 centimeter water), irrigation cost would total approximately $5,000 per hectare.

In the Lake Tahoe Basin, early spring seedings benefit from the high soil moisture remaining for some time after snow pack melt. Seedings conducted late in the year may suffer from frost heaving, particularly if a less than average snow pack exposes the seeded slope to repeated freezing and thawing during portions of the winter. Without installation of an irrigation system, repeated reseeding of critical areas may be required. In most instances, reseeding should not be required more than once. With good weather conditions and good timing neither reseeding nor an irrigation system would be required.

Seeding and Fertilization Costs. Individual varieties of seeds vary greatly in cost and may fluctuate from season to season and year to year depending upon market conditions. Costs may range from $1.20 per kg for Potomac Orchard grass to $3.65 per kg for Durar Hard Fescue. At the project sites, a wide variety of combinations of various grass seed, legume seed, and shrub seed mixtures were applied. For the seed unit cost estimates, various seed mixture unit costs were averaged to arrive at the following estimated values:

Grass Seed Mixture	$ 2.60/kg
Legume Seed Mixture	6.00/kg
Shrub Seed Mixture	19.00/kg

Fertilizer costs are estimated as follows:

16-20-0	$ .193/kg
Mag-Amp	1.203/kg
38-0-0	.638/kg
0-20-0	.180/kg

TABLE VIII-8

COMPARATIVE LABOR AND EQUIPMENT COSTS FOR VARIOUS DIRECT SEED AND FERTILIZER APPLICATION TECHNIQUES

(does not include cost of seed, mulch or fertilizer)

		DOLLARS/HECTARE	
	LABOR	EQUIPMENT	TOTAL
Applied with wood fiber hydromulch	---	----	$ 0/ha*
Hydroseeding followed by hydromulching at 2800 kg/ha	---	----	$ 79/ha*
Hydroseeding followed by hydromulching at 5600 kg/ha	---	----	$ 48/ha*
Hydroseeding before other mulch types	---	----	$348/ha*
Hand seeding at commercial rate ($13/hr + 25%)	$520/ha	$25/ha	$645/ha
Hand seeding by county workers rate ($10/hr)	$320/ha	$25/ha	$345/ha
Hand seeding by CCC workers ($5/hr)	$160/ha	$25/ha	$185/ha
Seed and fertilizer applied with range drill	$130/ha	$40/ha	$170/ha

*Note: These costs derived from CalTrans contracts.

Comparative unit labor and equipment costs of these various seeding techniques are shown in Table VIII-8. Costs for seeding utilizing hydromulching equipment are derived from Figure VIII-35.

The additional labor and equipment cost of simultaneous application of seed material and fertilizer with the hydromulching process is considered to be negligible. However, hydroseeding prior to mulching can increase the unit labor and equipment costs. If hydroseeding is conducted prior to hydromulching, a moderate increase in unit cost may be expected due to the additional use of the hydromulching equipment per unit area. If hydroseeding is conducted prior to a mulching technique other than hydromulching, the increase in unit cost can be significant due to the required use of hydromulching equipment which otherwise would not have been necessary. Hydroseeding is assumed to be conducted by applying wood fiber mulch at .20 metric tons per hectare (for visual metering and seed cushioning) and water at 10,000 liters per hectare with the appropriate amount of seed and fertilizer. Hand seeding and raking can be accomplished at a rate of approximately four person-days per hectare.

4. Mulching Techniques

Introduction. Several methods of seeding and mulching are available for vegetative erosion control. By combining various mulch rates and techniques, seeding rate and techniques, fertilizing rates and techniques, and tackifier rates and techniques, many methods with varying costs and degrees of effectiveness are available for use. Obviously, a project with time, space, and funding constraints cannot possibly demonstrate such a wide variety of mulching and seeding techniques. Rather, an attempt was made to choose those types of methods which, (1) were readily available for use in and around the Lake Tahoe Basin, (2) appeared to be relatively inexpensive, and (3) appeared to offer the greatest chance of successful revegetation of steep, severely eroding sites.

Basically, the seeding and mulching techniques demonstrated as part of this erosion control demonstration project fall into three general categories:

a. hydromulching
b. straw mulching
c. mulch nets and blankets.

In the following sections, these basic techniques and related variations are described and discussed, particularly as relating to their cost, effectiveness, and manner of use at the project demonstration sites.

Cost Estimating Procedures. The cost estimating procedures and assumptions listed at the beginning of this section were used in developing the cost data pertaining to seeding and mulching techniques. Information is based upon first-hand experience at the erosion control demonstration sites, communications with the California Department of Transportation, and communications with seeding and mulching contractors local to the Tahoe Basin and vicinity.

5. Wood Fiber Hydroseeding and Hydromulching

Hydroseeding is a method of applying seed (and fertilizer) to soil in a water slurry. Hydromulching, as used in this text, refers to the method of applying wood (cellulose) fiber (with or without seed and fertilizer) to the soil in a water slurry (see Figure VIII-34). Hydroseeding is an effective and a relatively inexpensive means of applying seed to a slope for revegetation. It requires a minimum labor force, but a fairly large capital investment in equipment. With rare exceptions, only commercial enterprises specializing in hydroseeding or hydromulching are available to conduct such an operation. The cost of hydroseeding equipment covers a wide spectrum from a few thousand dollars for 250 gallon units up to $100,000 for self powered 5,000 gallon units. Advantages of hydroseeding include uniform distribution of seed and fertilizer, access to steep slopes or areas too wet to sustain either pedestrian or heavy equipment traffic, and, if only commercial labor is available significantly lower cost than conventional hand seeding. Disadvantages include the necessity of a paved or otherwise firm surface near or adjacent to the area to be seeded, a readily available water supply, a high degree of capital commitment, and an inability to place the seed into the soil.

A wide variety of seeds, including grasses, legumes, shrub, and tree seeds may be used with the hydroseeding process. Large seeds (such as sugar pine) and extremely fragile seeds should not be used. The inclusion of legume seeds is not recommended unless the inoculant coating is durable (56). Poor success with legumes in the hydroseeding process

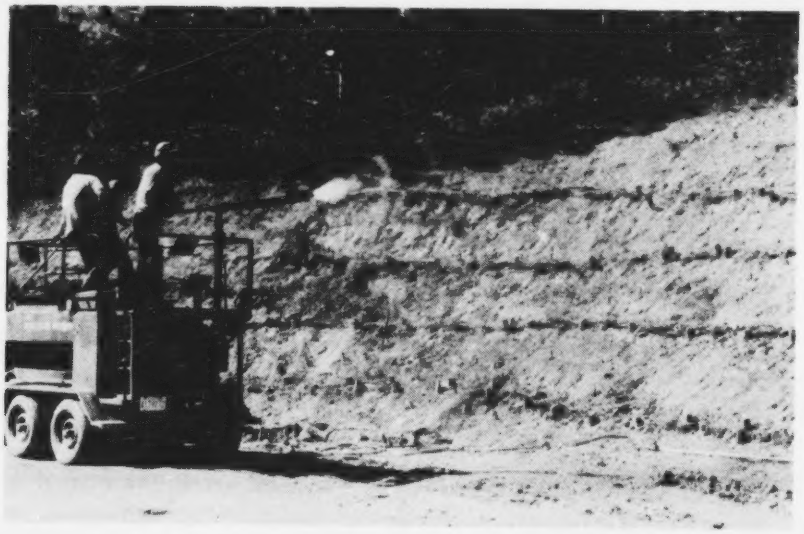


Figure VIII-34. Wood fiber hydromulching with seed and fertilizer in a one-step operation.

probably due to the extreme dilution of the inoculant when added to the mulch slurry. Grass, legume, and shrub seeding rates demonstrated at the project sites varied from 56 to 112 kg per hectare (50 to 100 lbs per acre). These rates, or even higher rates, are recommended for use with the hydromulching process.

The inclusion of a mulch when hydroseeding vastly improves the probability of successful seed growth and plant development. Generally, the mulch used with hydroseeding equipment is composed of fine wood fibers which, when agitated, disperse rapidly in water to form a uniform slurry. Wood fiber mulch is usually manufactured from aspen or alder wood chips with dispersing agents and dyes added. Wood fiber mulch manufactured from recycled waste paper is also available. Although this product is less expensive and less resource exploitative, other investigators have shown that it produces a less effective mulch cover (57). Other fibers composed of dairy waste fiber, ground straw, ground newsprint, recycled office waste, rice hulls, seed screenings, and cubed alfalfa may be available, but generally do not perform as satisfactorily as virgin wood fiber. Advantages of wood fiber include:

- formation of a strong, flexible mat which holds the seed and fertilizer in place until the seed has germinated
- insulation of seed and soil from solar radiation
- contains no weed seeds or other foreign seed
- uniform application assisted by non-toxic dyes which fade upon exposure to light
- cushioning of seed against damaging action of the mulching unit's pump

Wood fiber mulch is typically applied at rates ranging from 1,000 - 2,000 kg per hectare. Usually 1,580 kg per hectare is specified. When rates of about 2,000 kg per hectare or lower were demonstrated as part of this erosion control project on adverse sites, very poor results were obtained compared to that achieved with higher mulch rates. On the severely sloping (2:1 or greater), dry, exposed road cut and fill slopes found within the demonstration project sites, satisfactory results have been achieved only with mulching rates above 2,800 kg per hectare (2,500 lbs per acre). It appears that even greater success can be achieved with mulching rates approaching 5,600 kg per hectare (5,000 lbs per acre). It should be noted that such high rates are only recommended for the most severe erosion sites. Lower mulching rates should be sufficient on lesser (less than 2:1) slopes which are sufficiently moist or shaded. As is noted later in this report, due to economies of scale, a 100 percent increase in wood fiber mulching rate over a one-hectare area would normally increase the total cost of the operation only 30 to 40 percent.

Various commercially available chemical additives, both natural and synthetic, are advertised to hold mulch in place, promote germination, hold moisture, and reduce soil erodibility. Evidence from previous investigations (58) indicate that these additives, in most instances, do not significantly aid plant growth. Polyvinyl acetate (PVA) and styrene butadiene (SBR) were the only wood fiber mulch additives demonstrated as part of this project. The chemical additives transformed the flexible wood fiber mulch covering to a stiff plate-like covering which was susceptible to frost heaving and cracking. As a result, in most test plots where such additives were used, there was substantially less seed germination and growth.

Wood fiber mulch may be purchased with a organic tackifier already contained in the mulch (approximately 3 percent by weight). A substantial number of plots have been tested using pretreated wood fiber mulch at the Rubicon erosion control demonstration site. Initial evaluation, however, indicates that such pretreated mulch produces the same results as untreated mulch.

Hydromulching Costs

Mulch costs are highly dependent on the quantity of mulch purchased. It is furthermore assumed that a commercial operation would purchase wood fiber in 27 metric ton carload lots, which would allow the mulch to be purchased at the lowest possible price. In addition, it assumed that such carload prices are F.O.B. the San Francisco Bay area and that an additional $33.00 per metric ton would be required to transport the wood fiber to the Lake Tahoe area. The unit costs for wood fiber, thus derived are as follows (to the nearest dollar):

		Dollar/Metric Ton*
a.	Conwed^R	$200
b.	Conwed 2000^R (w/tackifier additive)	329
c.	Weyerhauser Silva Fiber^R	162
d.	Average for Untreated Mulch	181

Up to a 60 percent increase in unit purchase price may be expected if wood fiber mulch is purchased in 1 ton rather than 30 ton lots.

Unit hydromulching costs used in this report are derived from data extracted from current CalTrans contracts throughout California. The CalTrans contract data was available in the form of wood fiber mulch "in-place" costs for various contracts ranging in size from .14 hectare to 36.15 hectares. These costs include all materials, labor, and equipment required for the mulch placement, but do not include materials, equipment, and labor required for fertilizing, seeding, or chemical additives. CalTrans contracts specify 1.7 metric ton per hectare application rate for wood fiber mulch. The total cost, area covered, and mulching rate was used to determine the cost per unit of mulch for each of the various contracts. This data, after a format adjustment to dollars/metric ton versus metric tons, is shown in Figure VIII-35.

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*Prices as of June 30, 1976

It is assumed in this report, that the critical factor controlling job cost is the total amount of mulch applied rather than the total area covered. Assuming easy accessibility, it should not be significantly more expensive to cover 10 hectares with 5 metric tons of mulch than it would to cover 1 hectare with the same total amount. Thus, the cost data are presented in cost per unit weight rather than cost per unit area. Unit mulching costs may be readily obtained for a variety of mulching rates.

Cost data reported elsewhere (41) and obtained through personal communications with private contractors closely corresponds to the CalTrans data. Local contractors use as a practical "rule of thumb" that 0.4 hectare (1 acre) mulched at a rate of 1,680 kg per hectare (1,500 lbs per acre) should cost $600. This value is within 4 percent of the value determined from the information in Figure VIII-35 with allowances for seed and fertilizer costs.

Economies of scale, inherent in most equipment intensive endeavors, are apparent from the data presented in Figure VIII-35. For example, when the amount of mulch applied is increased by an order of magnitude from .68 metric tons to 6.8 metric tons, the unit cost is more than halved from $882 per metric ton to $392 per metric ton.

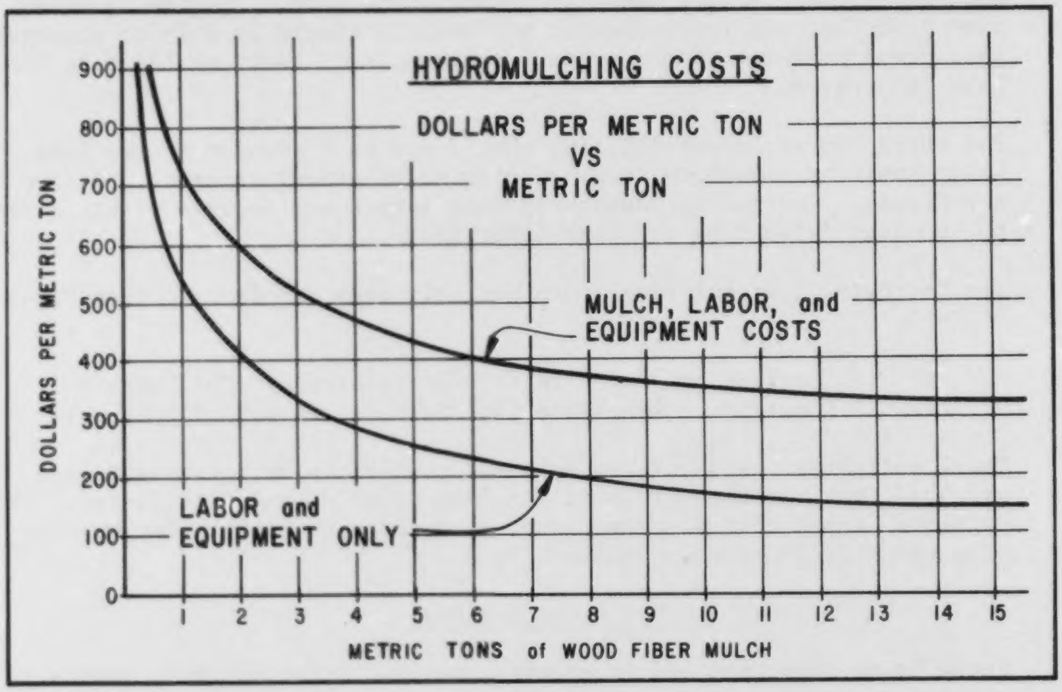

Figure VIII-35. Wood fiber hydromulching labor and equipment unit cost as a function of amount of mulch applied. Based on CalTrans contracts for first half of 1976.

There may be some questions as to whether or not this data is applicable to conditions found in and around the Lake Tahoe Basin. Unit costs are partially dependent on the difficulty of application of wood fiber at the construction site. These difficulties generally derive from three factors:

a. a readily accessible water supply
b. maneuverability of equipment
c. accessibility to job site

The first factor, water supply, should not be a major difficulty in and around the Lake Tahoe Basin. Arrangements may be made with the various water districts to tap the water supply system via fire hydrants in the towns, villages, developments, and subdivisions throughout the Tahoe area. Indeed, a majority of erosion problems which may be controlled through hydromulching exists in the form of oversteepened cut and fill slopes adjacent to roadways within these urbanized areas. Nevertheless, the use of hydromulching in more remote areas may require the use of water trucks, which would significantly increase the unit costs depicted in Figure VIII-35.

The second factor, maneuverability, may pose significant problems in steep, switchback, and narrow roadway areas, particularly if the equipment used is trailer-mounted rather than truck-mounted. However, in most instances, the equipment is likely to be large capacity (greater than 5,500 liters) truck-mounted units which should be able to negotiate most paved roadways in mountainous regions, such as those found in the Lake Tahoe area.

The third factor, accessibility, should not be a problem in the Lake Tahoe Basin or elsewhere in urbanizing or urbanized areas of California and Nevada. Several hydromulching contractors are located within a one to two hour drive from the Lake Tahoe Basin.

The following hydromulching costs per unit area are derived from Figure VIII-35.

a. 2.8 metric tons/hectare (2,500/lbs/acre) - $967/hectare
b. 5.6 metric tons/hectare (5,000/lbs/acre) - $1,353/hectare

These unit area costs reflect only the cost of labor, equipment, and overhead, not the cost of materials (mulch, seed, and fertilizer). The estimated total cost of hydromulching at three representative application rates is included in Table VIII-9.

6. Straw Mulching

Straw is an effective and inexpensive mulch. Straw mulch is generally applied either by a straw blower (Figure VIII-36) or by manual distribution. Advantages of a straw mulching operation over hydromulching include:

TABLE VIII-9

HYDROMULCHING AND SEED COSTS

	DOLLARS/HECTARE			
	LABOR & EQUIPMENT	MULCH	SEED & FERTILIZER*	TOTAL
Mulch at 1680 kg/ha	756	304	400	1,460
Mulch at 2800 kg/ha	967	506	400	1,873
Mulch at 5600 kg/ha	1,353	1,013	400	2,766

*Note: Grass, legume, and shrub seed mixture at 100 kg/ha.
16-20-0 fertilizer at 280 kg/ha.

- ability to utilize manual labor in difficult spots
- lightweight and easily maneuverable equipment
- lower capital investment for equipment
- no need for readily accessible water supply

However, unlike wood fiber hydromulch, straw mulch must be held down by a separate operation. Straw mulch may be incorporated into the ground by means of a crimper or a modified sheepsfoot roller. The use of a crimper or a modified sheepsfoot roller is limited to fairly level or gently sloping terrain. Straw mulch may also be held in place by the use of chemical tackifiers or nets. These incorporating and tackifying techniques are more fully described in the next section of this section. Major disadvantages of straw mulching include:

- separate applications of seed and fertilizer (usually manual)
- high incidence of weed seeds or seeds of foreign plant materials (use of rice straw significantly reduces the extent of this problem)
- application radius of straw blowing machine is severely limited, particularly under windy conditions
- need to incorporate or tackify the straw with soil immediately after application, and
- higher cleanup costs
- very costly at sites not accessible by straw blowing equipment

Like hydromulching units, straw blowing machines vary greatly in size and cost. Generally, an operation with experienced personnel and a large machine can be expected to mulch a large project at a rate of about 2.0 to 2.5 tons per hour.

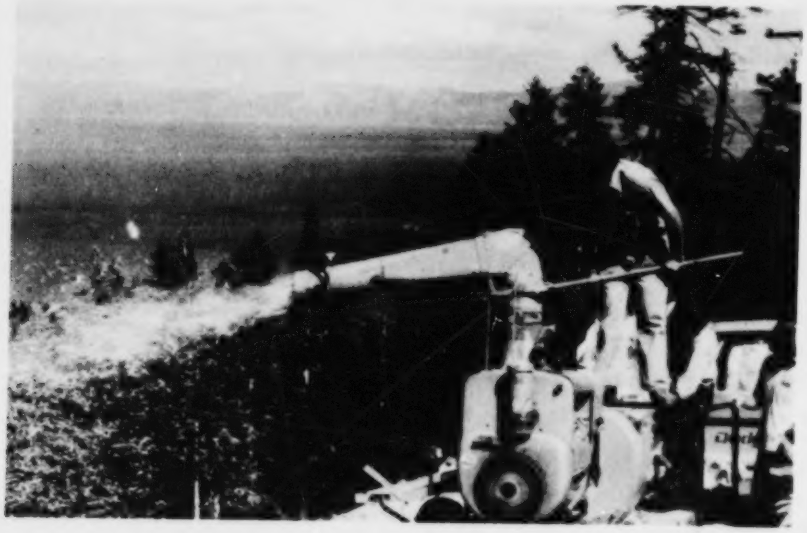

Figure VIII-36. Straw mulch application to fill slope by means of a straw blowing machine.

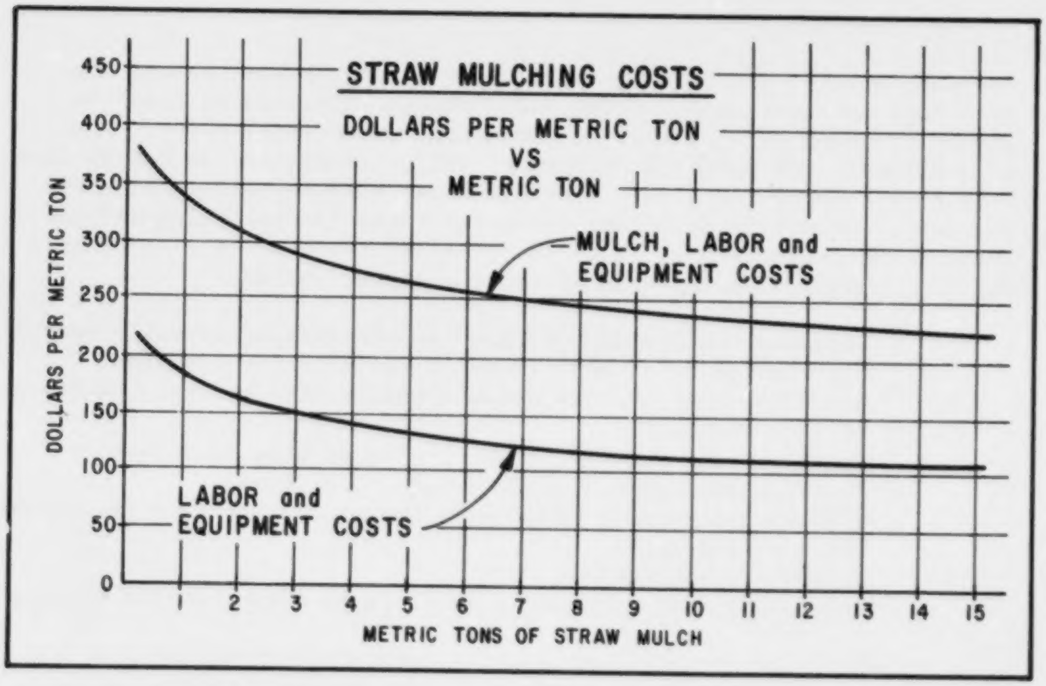

Figure VIII-37. Straw mulch application labor and equipment unit cost as a function of mulch applied. Based on CalTrans contracts for first half of 1976.

Many different straws are available for use. Straw used as part of this demonstration project have included: (1) rice straw, (2) barley straw, and (3) tall wheatgrass straw. Rice straw was the most difficult to use, as it was not chopped finely enough and tended to be distributed from the straw blowing machine in clumps. Rice straw does have the advantage of not containing seed of drought tolerant, foreign plants capable of surviving in high altitude mountainous regions of California and Nevada. Clean barley straw is easy to use if it is not baled too tightly. Barley straw is likely to contain a significant number of barley and weed seeds which may interfere and compete with the specified seeds, although the barley seedlings may provide considerable initial soil stabilization. Barley, however, is not likely to reproduce at higher elevations.

The straw tacking operation, described in the next section, should be conducted immediately after application of the straw, particularly if applied during windy weather. Untreated straw is very light and can easily blow away. Loose straw should be kept under control at all times. Situations can easily develop where loose straw combined with sediment and other detritus can clog and block drainage ditches, swales, gutters, drop inlets, and culverts. Cleanup operations must therefore begin immediately after straw is applied and tacked to an erosion control site.

Straw Mulching Costs. Straw mulch costs are also highly dependent on quantity purchased. Straw used for the project ranged from $33.00 per metric ton for 11 tons of rice straw purchased in 1975 to $25.00 per metric ton for 4 tons of barley straw purchased in 1976. Throughout this report the cost of straw is assumed to be $30.00 per metric ton F.O.B. Sacramento. With assumed transportation costs to Lake Tahoe of $15.00 per metric ton, the total price of straw for mulching is $45.00 per metric ton.

Straw mulching unit costs used in this report are derived from data extracted from current CalTrans contracts. The CalTrans contracts give straw mulch "inplace" costs for areas ranging from .32 to 176.06 hectares. CalTrans specifications require a straw mulch application rate of 9.0 metric tons per hectare (4 tons per acre). The cost data is presented in Figure VIII-37 (upper curve).

The lower curve in Figure VIII-37 depicts the unit labor, equipment, overhead, and profits of the straw flowing operation only. The costs of the mulch, $45 per metric ton, and the straw punching operation, estimated to be one-third of the overall contract price (41, 59), are not included.

The basic unit area used to compare erosion control costs in this report is 1 hectare (2.47 acres). It is felt that most contractors equipped for this operation would be willing to submit a bid on a project of this size.

The straw mulching technique using straw blowing equipment is only effective if the area to be mulched is within 20 to 30 meters of the available access road or surface. In areas that are unreachable using straw blowing equipment or in situations where inexpensive labor is readily available, it may be more practical and less costly to use hand labor to spread the straw mulch. Hand spreading labor and equipment costs become competitive with a commercial straw blowing operation if hourly wages are $5.00 per person-hour. Straw mulching labor and equipment equivalent costs are summarized as follows:

a.	Commercial straw blowing at 4.5 metric ton/hectare	$ 611/hectare
b.	Manual straw spreading at 4.5 metric ton/hectare	$1,613/hectare

Manual straw spreading equivalent costs are based upon the assumptions listed at the beginning of this section, including the assumption that total labor costs are equivalent to $16.25 per person-hour. County road crews, on the other hand, could manually spread straw at a cost of $963 per hectare, and CCC workers could manually spread straw for $517 per hectare. The total estimated costs of straw mulching and seeding, not including tackifier cost, is included in Table VIII-10.

TABLE VIII-10

STRAW MULCHING AND SEEDING COSTS

	DOLLARS/HECTARE			
	LABOR & EQUIPMENT	MULCH	SEED & FERTILIZER*	TOTAL**
Hydroseeded w/blown straw at 4,500 kg/ha	960	202	400	1,562
Hand seeded w/manual straw at 4,500 kg/ha	2,258	202	400	2,860

*Note: Grass, legume, and shrub seed mixture at 100 kg/ha. 16-20-0 fertilizer at 280 kg/ha.

**Note: Tackifier costs are not included and should be expected to cost an additional $1,000/ha.

Hand-spread straw and mechanically blown straw differ in length and contact with the soil. Blown straw pieces are shorter, sometimes split, and lie down better. Blown straw is generally easier to tack down, although the longer hand-spread straw may be superior for punching or crimping.

7. Chemical Tackifying Agents

A wide variety of natural and synthetic chemical mulch tackifiers and stabilizers are available for use. Some of the tackifiers may be applied directly to soils as a temporary stabilizer.

As discussed in the section on hydromulching, tacking of wood fiber hydromulch has achieved limited success, particularly in regions prone to severe frost heaving. On the other hand, straw mulching in areas which cannot be crimped or punched, requires the use of a tackifying agent. Asphalt emulsions are commonly used as straw tackifiers. Most commercial operators find that such asphalt emulsion sprays can be difficult to use, quite messy, and aesthetically unpleasing when applied to visible areas. For these reasons, representative samples of other types of products which can be substituted for asphalt emulsions were demonstrated as part of this erosion control project. Tackifiers demonstrated include:

- Terra Tack II^R, a free-flowing powder produced from seaweed extracts. This material is mixed with water and wood fiber mulch to form a slurry which is applied as an overspray to a previously straw mulched site. When mixed properly, it polymerizes and, upon application, forms an insoluble network of binding membranes.

- Terra Tack II^R Super Concentrate, an experimental free-flowing powder similar to Terra Tack II^R but which may be applied simultaneously with the straw mulch at somewhat lower rates. This material is mixed with water and a small amount of wood fiber to produce a slurry. This product proved ineffective and has been removed from the market.

- Ecology Controls M-Binder^R, a free-flowing powder produced from a plant gum (Plantago insularis). This material has received limited use as a straw tackifier and was developed primarily as a wood fiber mulch binder and soil stabilizer. It is mixed with water and wood fiber to form a slurry which is applied as an overspray to the previously straw mulched site.

- Styrene butadiene copolymer emulsion (SBR), a synthetic polymer in the form of a white, milky translucent liquid which forms a thin insoluble coating when applied and allowed to dry. This material is mixed with water, a methyl cellulose modifier, an anti-foaming agent, and wood fiber mulch to form a slurry. When applied simultaneously with a straw blowing operation, the amount of wood fiber mulch should be kept to a minimum to prevent clogging of the apparatus.

- Wood fiber only, which is wood fiber applied as a tackifier with a hydromulcher at somewhat lower than normal rates. On experimental plots at the erosion control project sites, sprayed wood fiber mulch at 800 kg/ha was as effective as any other tackifier which was used.

TABLE VIII-11

RECOMMENDED STRAW MULCH TACKIFIER APPLICATION RATES

TACKIFIER	SHIPPED WEIGHT kg/ha	MODIFIER kg/ha (if any)	WOOD FIBER kg/ha	WATER liter/ha	SLURRY liter/ha
Terra Tack II^{R} (powder)	100	N/A	336	14,000	14,000
Terra Tack II^{R}- Super Concentrate (powder)	50	N/A	75	5,340	5,340
Ecology Control M-Binder^{R} (powder)	150	N/A	225	8,750	8,750
SBR (Dow XFS 4163-L)	750 (745 l/ha)	10.2	(up to 460)	4,250	5,000
Asphalt Emulsion	4,400 (4,600 l/ha)	N/A	N/A	N/A	4,400
Wood Fiber	800	N/A	800	16,800	17,000

The recommended application rates for these materials for steep and/or difficult erosion control sites are shown in Table VIII-11. All the materials demonstrated, except Terra Tack II^{R} Super Concentrate, have been tested by others (60) under controlled conditions and at the recommended rates have a tacking strength comparable to asphalt emulsion. Of the materials demonstrated, the powders appear to be the simplest to use and require considerably lower shipping costs than do liquid tackifiers, such as SBR or asphalt emulsion. Both SBR and asphalt also appear to require more involved cleanup procedures than do the powders.

Tackifying Costs. The following tackifier materials costs are based upon manufacturers' quotations, including shipping but not wood fiber mulch costs (if required):

		$/kg	$/ha*
a.	Terra Tack^R II^R	$ 6.35	$635
b.	Terra Tack^R Super Concentrate	$11.35	$568
c.	M-Binder^R	$ 4.65	$698
d.	SBR	$ .80	$600
e.	Asphalt Emulsion	$ .20	$880
f.	Wood Fiber only	$ .18	$144

* Cost per hectare for tackifier only based upon recommended application rates. Lower unit costs may be achieved by purchasing materials in large quantities.

The two basic application methods for mulch tackifiers are: (1) simultaneous application with the mulch, and (2) overspray application of tackifier after the mulch is in place. The overspray tackifier application method is usually accomplished using a hydromulching unit. An asphaltic tackifier is applied with an asphalt rig or simultaneously with a gear pump provided with most mechanical straw blowers.

It is estimated that the simultaneous tackifier application should only increase the labor, equipment, and overhead costs of the straw blowing operation by about 10 percent. This is particularly true if the commercial enterprise is familiar and experienced with the methods involved. A two-stage application of tackifying agents can substantially increase the labor, equipment, and overhead cost of the mulching operation. The separate, overspray addition of the tackifier necessitates additional hydromulching or spraying equipment and labor not otherwise required. The cost of overspraying a tackifying agent is assumed in this report to be equivalent to the "per liter" cost of applying a wood fiber mulch slurry minus the material cost of the mulch. The wood fiber mulch slurry application costs are based upon recent CalTrans contracts and the assumption that a commercial operation requires 21 liters of water for every kilogram of wood fiber mulch applied (twenty 50 pound bales per 2,500 gallons water).

The unit labor, equipment, and overhead costs for tackifier application via a hydromulching unit are summarized in Figure VIII-38. For example, application rates for labor, equipment, and overhead cost per unit area are as follows:

a. 5,000 liters/hectare - $227/hectare
b. 10,000 liters/hectare - $348/hectare

Due to economies of scale, a 100 percent increase in tackifier application rate from 5,000 to 10,000 liters per hectare results in only a 53 percent increase in labor, equipment and overhead costs. The total estimated materials, equipment, and labor cost required for the installation of various tackifiers, based on recommended application rates, are listed in Table VIII-12, assuming a hydromulching unit is used to apply the tackifier over the straw, as pictured in Figure VIII-39.

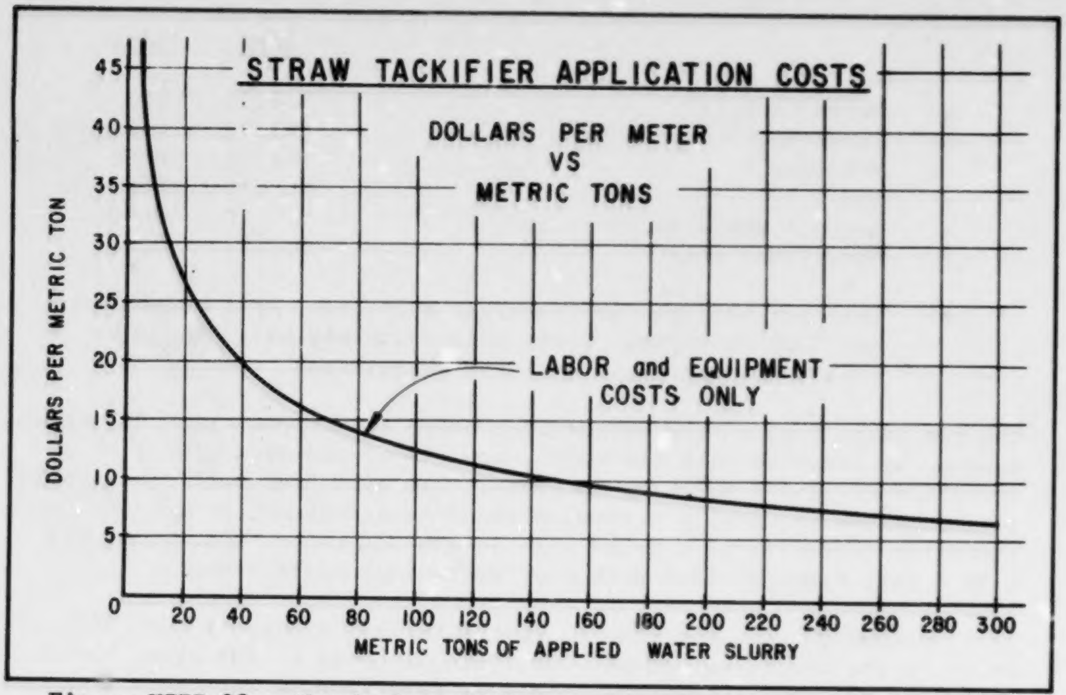

Figure VIII-38. Chemical tackifier application labor and equipment unit cost when applied as a water base slurry with hydromulching equipment. Based on CalTrans contracts for first half of 1976.

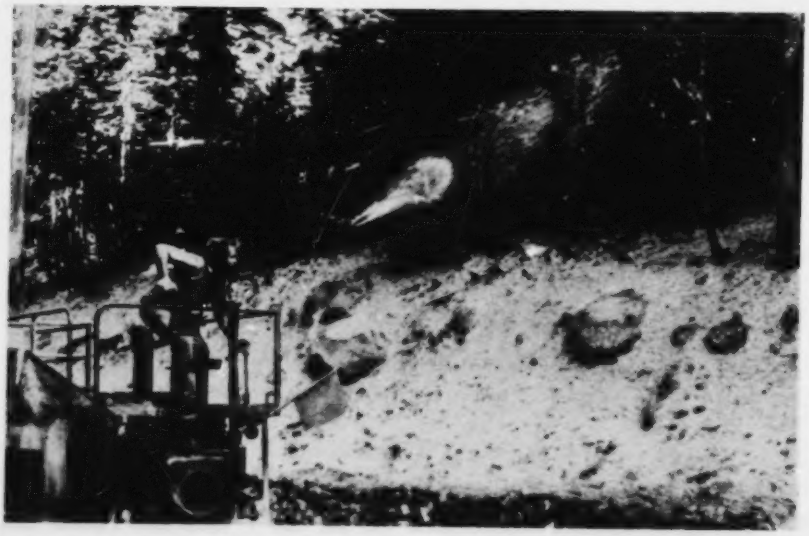

Figure VIII-39. Application of a chemical tackifier over straw mulch using hydromulching equipment.

TABLE VIII-12

ESTIMATED TACKIFIER COST APPLIED OVER STRAW MULCH

	DOLLARS/HECTARE		
TACKIFIER	ALL MATERIALS	LABOR & EQUIPMENT	TOTAL
Terra Tack II^{R}	\$696	\$426	\$1,122
Terra Tack II^{R} -S. C.	\$582	\$236	\$ 818
M-Binder^{R}	\$739	\$321	\$1,060
SBR	\$683	\$227	\$ 910
Asphalt Emulsion	\$880	\$720	\$1,600
Wood Fiber only	\$144	\$600	\$ 744

8. Mulch Nets and Blankets

A variety of mulch nets and blankets are available for placement over seeded and fertilized areas. These products temporarily stabilize the soil until the seeded plants have matured. Use of mulch nets and blankets can be advantageous in that experienced commercial contractors and expensive equipment are not required for their installation. Nonetheless, the mulch nets and blankets themselves are quite expensive and require a considerable amount of manual labor to install. As will be subsequently shown, the use of mulch nets and blankets becomes economically competitive in the Lake Tahoe-Sierra Nevada Region only if extremely inexpensive or volunteer labor is available. In addition there is no evidence at the demonstration sites to indicate that mulch nets and blankets are particularly more effective in establishing plant growth or providing temporary soil stabilization than other, less expensive mulching techniques. A possible exception would be in the case of extremely sloping terrain (steeper than 1½:1).

The mulch nets and blankets demonstrated as part of the erosion control project are the following:

- Excelsior^{R} Blankets, a machine produced mat of curled wood excelsior which is evenly distributed throughout the blanket. The top side of each mat is covered with a biodegradable plastic mesh. The mats are generally produced in rolls with a coverage of either 67 or 84 square meters each. On slopes, the excelsior is rolled out from top to bottom with one 15 centimeter "U" shaped staple per square meter, as shown in

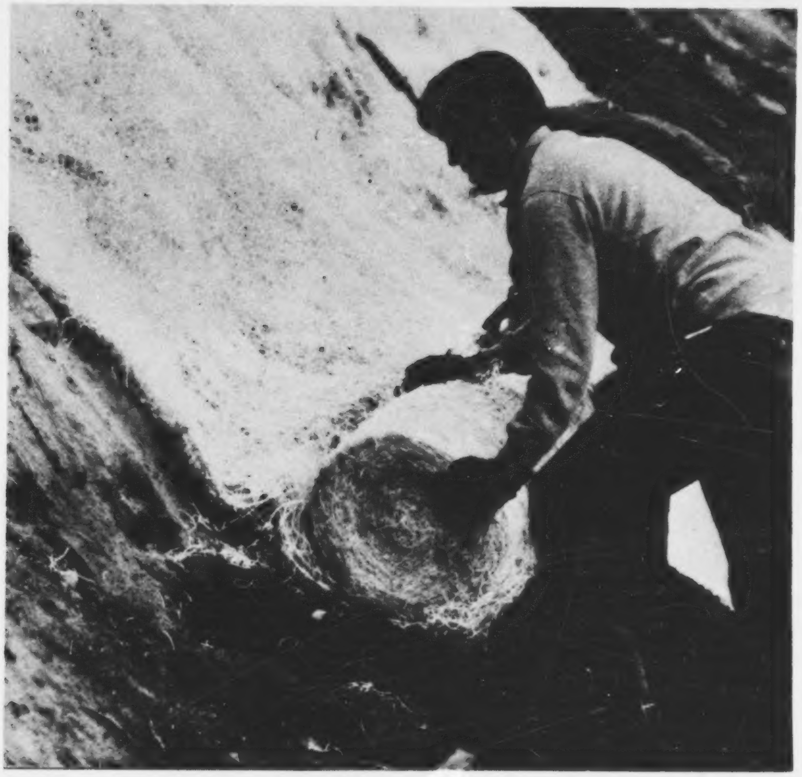

Figure VIII-40. Manual application of Excelsior^R blanket over a seeded and fertilized cut slope.

Figure VIII-40. It is not necessary to dig check slots, anchor ditches, bury the ends of blankets, or provide extensive slope preparation.

- Plastic Netting, a rectangular mesh of extruded, biodegradable plastic strands. The netting generally comes rolled on a cardboard core in widths of 2.3 or 4.6 meters. The total area covered by a 4.6 meter wide roll is 3,500 square meters. The area to be covered must be a smooth raked surface, free of rocks, clumps of plants, or anything else which prevents the close contact of the net to the surface. The area must then be seeded and mulched according to accepted practices and the plastic netting placed in lengths from the top to the bottom of the slope, overlapping 5 to 10 centimeters with the adjacent length. Staples, 15 centimeters in length, are evenly distributed at approximately one staple per square meter in a diagonal pattern.

- Jute Mesh, a heavy netting of uniform open plain weave, loosely twisted jute yarn. The jute mesh is furnished in 40 kilogram rolled strips which cover approximately 80 square meters each. The area to be covered must be a smooth surface, free of rocks, clumps of plants, or anything else which would prevent close contact between the mesh and the ground surface. The area is then seeded and fertilized according to accepted practices. A light covering of mulch may also be applied. The jute mesh is then rolled from the top to the bottom of the slope and held in place using 15 centimeter "U" shaped staples. The mesh must be applied loosely without stretching. The upper and lower ends of the mesh must be buried or otherwise firmly secured. Where two or more lengths are applied side to side, an overlap of at least 10 centimeters must be made. The staples should be evenly distributed in a diagonal pattern with approximately one staple per square meter. A steeply eroding road cut at the Rubicon Properties erosion control project site treated with jute netting is shown in Figure VIII-41.

- Paper Fabric, a combination of thin paper strips interwoven with synthetic yarn mesh. Both the paper and synthetic yarn are degradable. A wide range of yarn-paper durability and thickness is available depending upon specific site conditions and the need for slow or rapid degradation of the fabric. The paper fabric is furnished in widths of 1.5 or 3 meters. The larger width is folded double and shipped in rolls weighing

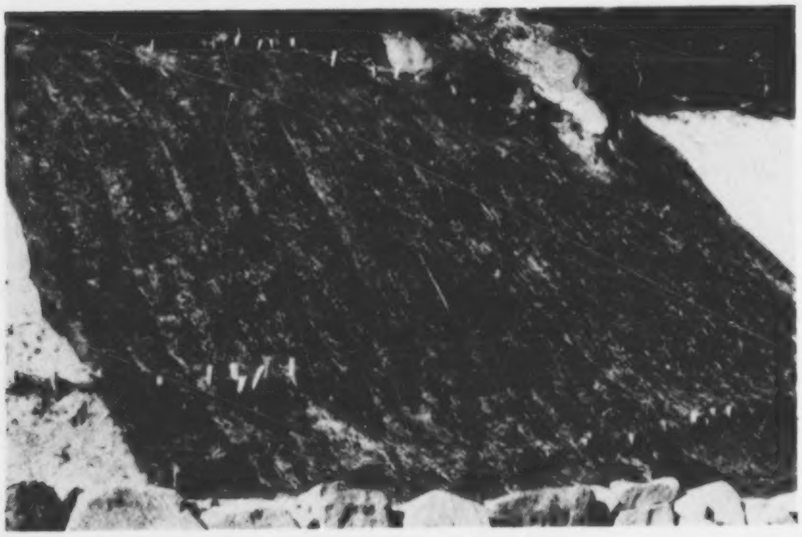

Figure VIII-41. Jute netting applied to a seeded and fertilized slope.

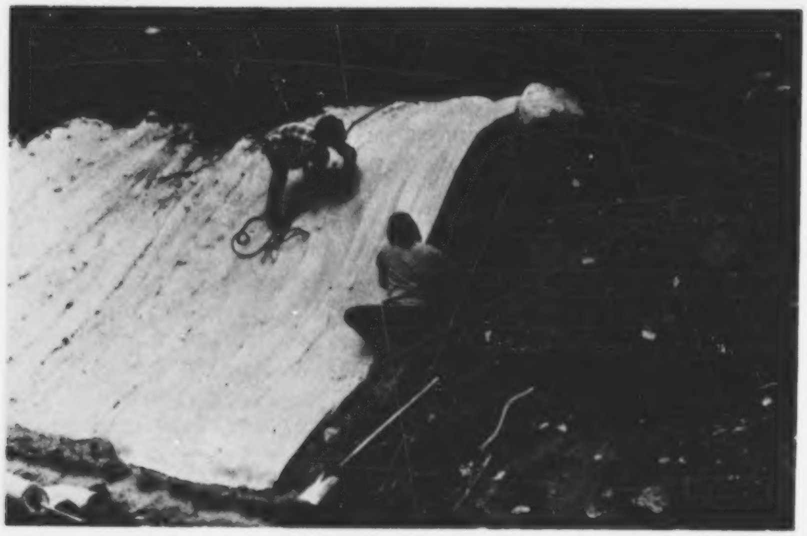

Figure VIII-42. Manual application of paper fabric blanket over a seeded, fertilized, and straw mulched severely eroding cut slope.

approximately 36 kilograms each and is able to cover approximately 325 square meters. The area to be covered must be smooth, free of rocks, clumps of plants, or anything else which would prevent close contact between the paper fabric and the ground surface. The area is then seeded and fertilized according to accepted practices. A light covering of wood fiber or straw mulch may also be applied to the slope face. The paper fabric should be loosely applied to the ground surface, with no introduced tension or bridging above the ground surface. Adjoining strips of paper fabric must be overlapped 10 to 15 centimeters. Staples, "U" shaped, and 15 centimeters in length are evenly distributed at one staple per square meter to hold the paper fabric in place. A 10 to 15 centimeter deep check ditch should be constructed 30 centimeters back from the slope crown and at the toe of the slope. The top and bottom edges of the paper fabric should be stapled in these check slots at 20 to 25 centimeter intervals and buried. Lateral edges of the covered area should also be heavily stapled and buried to insure against water channeling or lifting by heavy winds.

All of the above-mentioned materials appear to perform well as mulch nets and blankets. Advantages of mulch nets and blankets over other mulching methods include:

- direct physical attachment of mulch materials to soil surface
- can sustain moderate foot traffic once in place

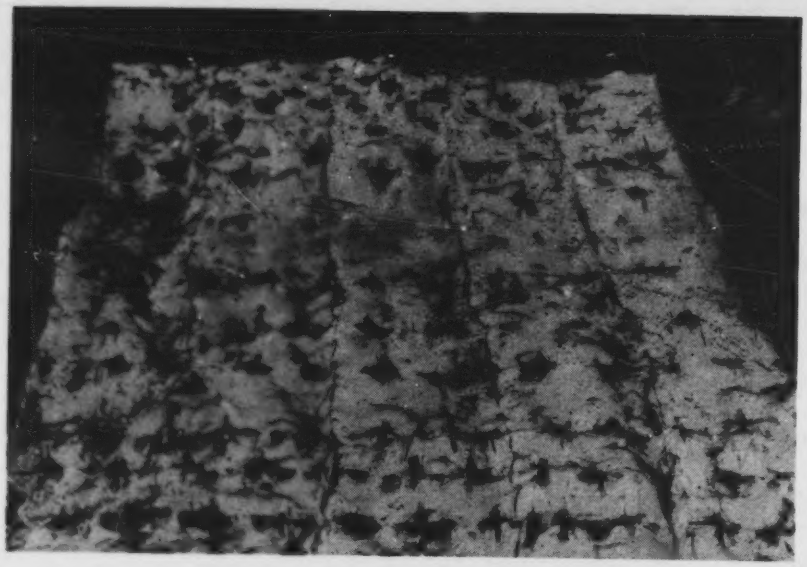

Figure VIII-43. Penstemon plants sprigged through a slope covered with paper fabric which helps retain the soil moisture and inhibit erosion.

- after placement, openings may be cut for sprigging plants as shown in Figure VIII-43
- usually durable and long lasting
- usually provides some moisture retention
- less subject to foot or vehicle traffic as treatment is more obvious than hydromulched or straw tacked slope

Disadvantages include:

- extremely high materials cost relative to other mulches
- extremely high manual labor requirement relative to other mulches
- foot traffic required for installation may dislodge previously placed seed on steeper slopes
- unsightly and may require eventual removal

Of all the mulch nets and blankets tested, the Excelsior^{R} blanket and jute mesh appear to provide the best coverage and adherence to the soil surface. The paper fabric appears effective in retaining soil moisture even on very dry, exposed slopes. The plastic netting provides an inexpensive way to apply straw mulch to erosion control sites if straw blowing equipment is not readily obtainable and low cost manual labor is available.

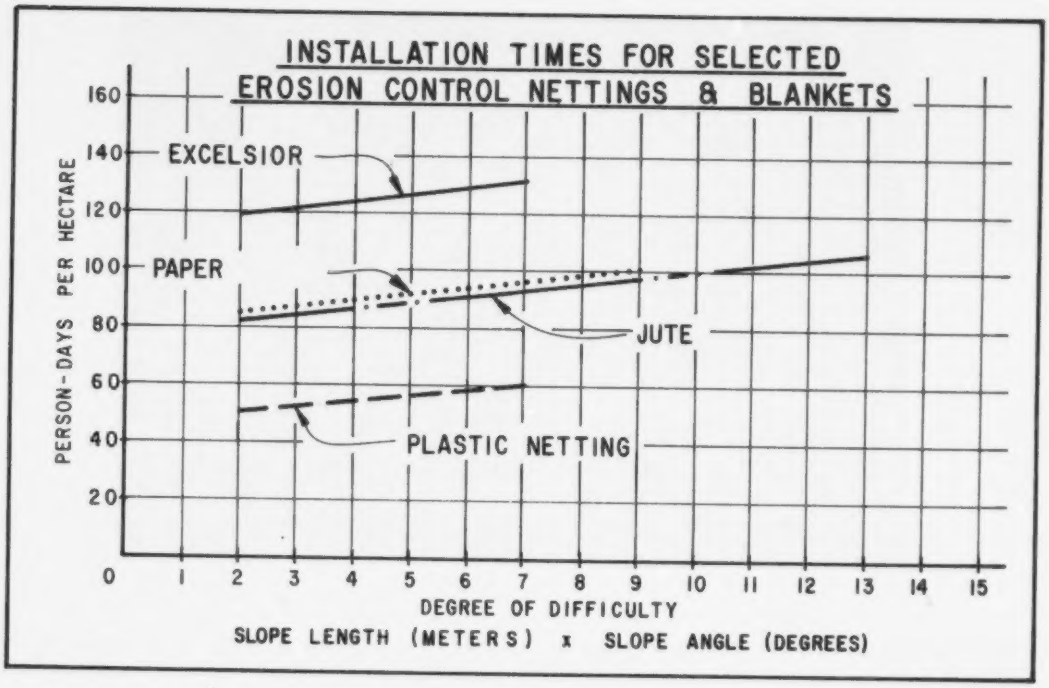

Figure VIII-44. Labor requirements for the manual installation of various erosion control nettings and blankets.

Mulch Net and Blanket Costs. The costs of mulch nets and blankets are calculated based upon coverage of a one-hectare job site. Since the use of nets and blankets is relatively uncommon in the Sierra Nevada-Lake Tahoe area, it is assumed that these materials would not be purchased in lots larger than that necessary to cover each job. Shipping costs are dependent upon the location of the nearest distributor and the relative weight per unit area of the material. The following materials costs are based upon information provided by various manufacturers and include estimated shipping costs:

		$/hectare Total
A.	Excelsior^R Blanket	$3,404
B.	Plastic Netting	$1,293
C.	Jute Mesh	$5,294
D.	Paper Fabric	$5,814

In all of the above cases, shipping costs do not exceed 5 percent of the retail cost of the materials.

The cost estimates of labor required for installation of nets and mulch blankets varies widely depending on the source. One manufacturer of jute mesh claims that, with proper installation procedures, jute may be installed at rates as low as 15 person-days per hectare. On the other hand, a recent EPA publication (3) indicates installation rates may run as high as 103 person-days per hectare for steep slopes. The steepness and length of slopes does affect, to a moderate degree, the amount of labor required to install these types of materials. Data gathered at the Rubicon Properties erosion project site demonstrates this. The severely eroding road cut slopes at Rubicon, where nets and blankets were used, have slope angles ranging from 31 degrees (1.66:1) to 45 degrees (1:1) and slope lengths ranging from 4.6 meters to 14.3 meters. For this range of slope difficulties, the term "degree of difficulty" is used to empirically describe the slope conditions, which is simply the slope length multiplied by the tangent of the slope angle. The "degree of difficulty" is simply a method of correlating the increased manpower commitments required for the installation of nets and mulch blankets as the length and steepness of the slope increases. Figure VIII-44 depicts the person-hours of installation time for the four types of nets or mulch blankets used as part of the erosion control demonstration project.

Jute netting and paper fabrics appear to have similar manpower requirements. Jute weighs considerably more than paper fabic. Thus, jute requires more effort to spread. Once positioned on the slope, however, jute has less of a tendency to be disturbed by wind and is easier to work with and move around on. From experience gained at the project site, Excelsior^R blankets require approximately 40 percent more installation time than either jute or paper fabric. The smaller width of the excelsior roll necessitates approximately 15 to 20 percent more trips up and down a slope to place the material. Two advantages of the excelsior are, (1) as claimed by the manufacturer, the material at the top and bottom of the slope does not need to be buried, and (2) excelsior blankets may be formed around slope irregularities such as rocks or clumps. Plastic netting, over straw, appears to require about 40 percent less installation time than does jute or paper fabric on steep slopes. This is due primarily to the extremely light weight of the material and the larger width (4.6 meters) of the plastic netting rolls. Both the plastic netting and the Excelsior^R blanket are almost impossible to use on very steep slopes. As a result, these two materials were not used on slopes with a steepness greater than 1½:1.

For a 10-meter slope with a steepness of 1½:1, the labor requirements and cost comparisons are derived from Figure VIII-44 and depicted in Table VIII-13.

9. Fiberglass Roving

Fiberglass roving is actually a type of mulch blanket. It was not used at either the Northstar or Rubicon Properties erosion control project sites, and is thus treated separately. Fiberglass roving was not used at the project sites for the following reasons:

TABLE VIII-13

EQUIVALENT EQUIPMENT AND LABOR COSTS FOR INSTALLATION OF MULCH NETS AND BLANKETS

		DOLLARS/HECTARE			
	PERSON-DAYS PER HECTARE	MATERIALS	EQUIPMENT	LABOR	TOTAL*
Excelsior	$130.5	$3,404	$804	$16,965	$21,173
Plastic Netting	60.0	1,293	370	7,800	9,463
Jute	93.5	5,294	576	12,155	17,449
Paper Fabric	95.5	5,814	588	12,415	18,229

*Note: Does not include seed, fertilizer or other mulch costs.

- aesthetic and environmental concerns regarding its use
- the close proximity of an extensive experimental fiberglass roving installation near the Rubicon Properties erosion control project site (El Dorado County milepost 22.8 on State Highway 89)

Fiberglass roving is formed from molten glass. It is manufactured for a variety of products that utilize fiberglass and commonly is produced in a coiled package. The roving is fed through a special nozzle connected to an air compressor. The compressed air propels and separates the strands of glass fibers, spreading them evenly over the ground surface. A tack coat of asphalt (or other tackifier) is applied over the roving to bind the strands together and to insure adhesion to the soil (61). At the experimental fiberglass roving site near Rubicon Properties, the area was seeded with grasses and native shrub seeds and fertilized prior to the roving application. The application of fiberglass roving is pictured in Figure VIII-45. Fiberglass roving has also been effectively used by CalTrans to control erosion in drainage ditches and swales.

Fiberglass roving has the disadvantage of being nonbiodegradable and, if associated revegetative measures do not succeed, will leave an unsightly slope covering. Considerable objections have been raised regarding the use of synthetic or nonbiodegradable materials for erosion control within the Lake Tahoe Basin. This is particularly true for materials such as fiberglass roving with its obviously unnatural appearance.

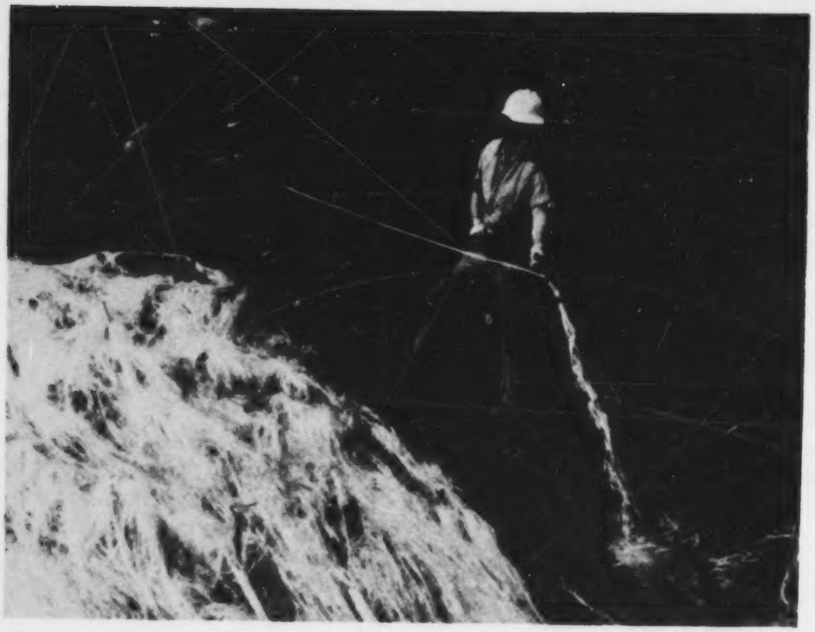

Figure VIII-45. Application of fiberglass roving with a compressed air gun.

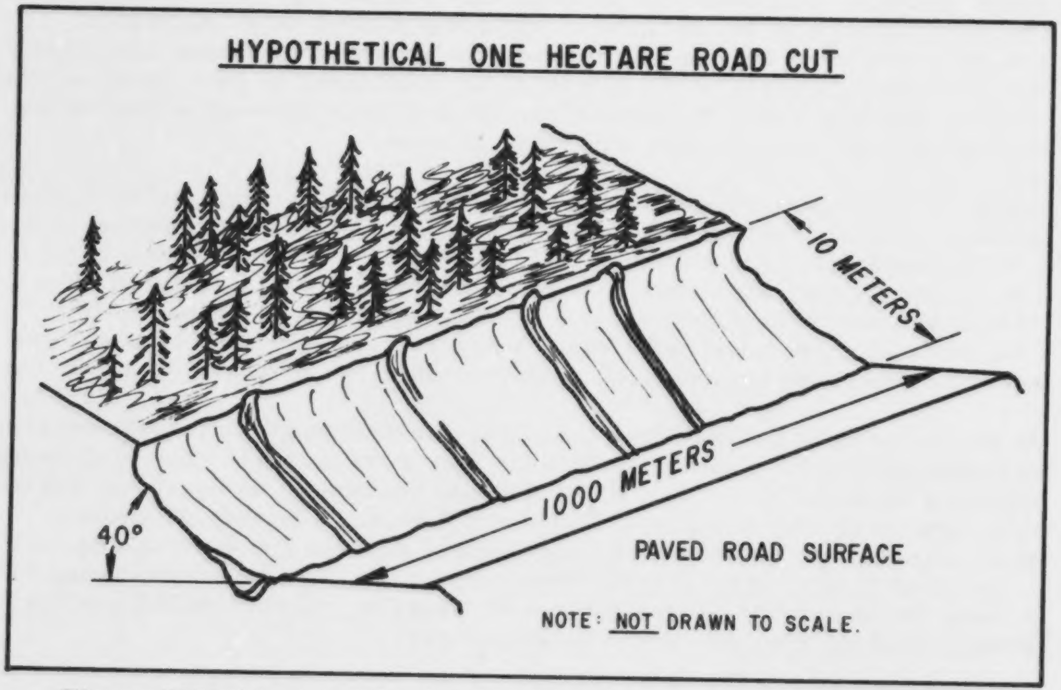
HYPOTHETICAL ONE HECTARE ROAD CUT
10 METERS
1000 METERS
40°
PAVED ROAD SURFACE
NOTE: NOT DRAWN TO SCALE.

Figure VIII-46. Hypothetical one hectare steep, eroding, cut slope adjacent to a road surface.

Roving Costs. CalTrans recommends that fiberglass roving be applied to a site within 24 hours after normal seeding operations have been conducted. The fiberglass roving itself should be applied uniformly to form a random mat of continuous glass fiber at a rate of 0.15 to 0.20 kilogram per square meter. Asphaltic material applied over the roving should be applied at a rate of 1.10 to 1.60 liters per square meter. It is recommended that the upgrade end of the roving be buried in a shallow ditch above the crown of the slope. Total treatment cost for fiberglass roving, including seed and fertilizer, was estimated by CalTrans to be about $6,000 per hectare in 1974. Estimated installed cost for fiberglass roving as of July 1976 is $8,000 per hectare.

G. Comparative Erosion Control Costs

The preceding pages of this section have described in detail a wide variety of erosion control measures. Where possible, an individual breakdown of unit materials, equipment, and labor costs is provided with each method. The reader should refer to individual methods and to the assumptions listed at the beginning of this section to determine how individual cost estimates were developed. Particular attention in the demonstration project has been paid to the most cost-effective methods for erosion control on oversteepened slopes in and around the Lake Tahoe Basin of California. A "hypothetical" eroding cut slope is used for the purpose of cost comparison. Such a hypothetical 1.0 hectare eroding cut slope is pictured in Figure VIII-46. The slope has an average slope length of 10 meters and runs for 1,000 meters adjacent to a paved roadway. It is further assumed that the cut has an average slope angle of 1.25:1 and is continually sloughing eroded material into a poorly constructed drainage structure running along the slope toe. For all practical purposes, this situation is considered to be typical of the erosion problems found throughout the Tahoe-Sierra although actual slope dimensions vary considerably from case to case.

Table VIII-14 summarizes the unit costs and the total costs of selected erosion control techniques if they were applied to the hypothetical 1.0 hectare road cut. The column entitled "percent labor" refers to the percentage of the total unit cost which is devoted to labor costs at $16.25 per person-hour. Those percentages which are followed by an asterisk indicate those tasks where a majority, if not all, of the labor could be performed by unskilled conservation corps workers.

As can be seen in Table VIII-14, erosion control costs vary considerably. Alternative erosion control techniques vary from a single pass with hydromulching equipment at a cost of $1,800 per hectare to an extensive gabion revetment structure costing $227,800 per hectare. Neither of these approaches should be considered appropriate methods for controlling erosion on this type of slope. Based upon the various methods demonstrated at the Northstar and Rubicon Properties erosion control project sites, the best approach would be as follows:

Hypothetical Scenario

1.	Construct a curb, gutter and bench system at the toe of the eroding slope	$15,620/1000 meters
2.	Manual scaling and overhang removal	9,644/ha
3.	Debris cleanup and removal	4,086/ha
4.	Three rows of contour willow wattling	18,420/3000 meters
5.	100 kg/ha of seed materials covered with 4,500 kg/ha straw mulch and chemical tackifier treatment	2,200/ha
	TOTAL	$49,970/ha

It is important to note that all labor costs for the above methods are assumed to be $16.25 per person-hour. Total erosion control costs may be reduced significantly if conservation corps workers are used on portions of the tasks requiring unskilled laborers. For example, if conservation corps workers costing approximately $5.00 per person-hour were used where possible to perform nonskill oriented tasks the total cost of the above erosion control scenario would be reduced from $49,920 per hectare to $30,387 per hectare. This represents almost a 40 percent cost reduction. Nevertheless, even if conservation corps workers are used to the fullest extent, almost 25 percent of the labor required must still be performed by skilled or semi-skilled laborers using heavy or specialized equipment.

Certain situations will arise when application of the above scenario may be difficult. The construction of a curb, gutter, and substantial bench system at the toe of the slope requires commitment of a portion of the road right-of-way for this purpose. In some instances, this may require reduction of the required paved road surface or shoulder to less width than is required by state law or county ordinance. If this is the case, then either, 1) exceptions must be made to allow for the construction of a curb, gutter, and bench system, or 2) other alternative stabilization techniques must be employed. If a rock or gabion breast wall were constructed in place of a curb, gutter, and bench system at the edge of the existing road shoulder, the total cost for implementation of the above scenario would be almost doubled from $49,970 per hectare to over $93,000 per hectare. Because of the considerable added expense the construction of major breast wall structures should be avoided wherever possible.

Other substitutions may be made in the above scenario depending upon the resources available to perform the required tasks. However, no alternative scenarios are likely to be as cost-effective as the one listed above for severe, steeply eroding slopes. All of the selected erosion control methods listed in Table VIII-14 will be effective in controlling erosion if used in the proper situations.

H. Preliminary Evaluation of Erosion Control Effectiveness

This erosion control project has resulted in the construction and implementation of various erosion control demonstration plots at Northstar-At-Tahoe and Rubicon Properties. These demonstrations were conducted at

TABLE VIII-14

COMPARATIVE EQUIVALENT UNIT COSTS FOR SELECTED EROSION CONTROL METHODS USED ON OVERSTEEPENED SLOPES

MECHANICAL STABILIZATION	UNIT COST	% LABOR	COST PER HYPOTHETICAL HECTARE
Curbs and Dikes	\$ 15.62/m	50	\$ 15,620
1.00m Rock Breast Wall	61.16/m	45	61,160
0.90m Gabion Breast Wall*	58.61/m	52*	58,610
2.70m Gabion Retaining Wall*	190.48/m	52*	190,480
Manual Slope Scaling*	42.68/m^3	96*	9,644
Cleanup & Debris Removal*	0.41/m^2	96*	4,086
Contour Wattling*	6.14/m	82*	18,420
Gabion Revetments*	27.78/m^2	40*	277,800
Concrete Anti-erosion Grids	24.67/m^2	48	246,700
Gunite Revetments	10.76/m^2	27	107,600
REVEGETATION			
Willow Staking*	\$ 0.60/stake	95*	\$ 24,000
Rooted Shrub Cuttings*	1.36/plant	60*	54,400
Bare Root Seedlings*	.63/plant	86*	26,080
Seed w/2800 kg/ha Hydromulch	.18/m^2	30	1,800
Seed w/5600 kg/ha Hydromulch	.27/m^2	30	2,700
Seed w/4500 kg/ha Tacked Straw	.22/m^2	30	2,200
Seed w/Jute*	1.84/m^2	70*	18,400
Seed w/Paper Fabric*	1.92/m^2	68*	19,200
Seed w/Excelsior*	2.16/m^2	79*	21,600
Seed w/Straw & Plastic Net*	1.07/m^2	73*	10,700
Seed w/Fiberglass Roving	.80/m^2	N/A	8,000

* Those tasks where a large portion of the work may be performed by unskilled conservation corps laborers.

Northstar and Rubicon Properties from the summer of 1976 through the spring of 1977. Prior to 1975, the Soil Conservation Service (SCS) also established a number of shrub and herbaceous planting demonstration plots at Northstar in the spring of 1973 and the spring of 1974. In all cases, the demonstration plots were intended to identify and demonstrate the effectiveness of techniques which could be used to control the various types of slope stabilization and erosion problems which were found at the project sites. In the case of Northstar, only a few scattered erosion problems could be identified. The Rubicon Properties project site, on the other hand, required extensive erosion control and slope stabilization corrective measures on over 13 percent of the subdivision's land surface. Complete descriptions of the plots and the various combinations of demonstrated techniques which were conducted as part of this project and as part of the previous work by the SCS are given in Appendix B of this report.

The plots at Northstar and Rubicon Properties demonstrate the wide range of technologies available to stabilize and revegetate severely eroding slopes. It is estimated that these various types of "source control" techniques will be effective in reducing previous erosion and sediment yield rates by 80 to 90 percent. Any erosion control technology can be deemed successful, however, only if it withstands the test of time. Time has not yet enveloped this demonstration project, so only preliminary observations and comparisons can be made.

Toe Stabilization. Rock walls and gabion baskets seem equally effective when properly positioned and constructed. The large rocks in walls have channeled water to low spots between rocks and caused some erosion at those points. The gabion baskets have received multiple wounds from snow plows. They are particularly vulnerable to this type of damage, and ideally should be thoroughly snow staked. Repair of damage has proven difficult because of rolled asphalt gutters at the base of baskets. Gabions are also considered very ugly by most people. They gradually fill with dirt, however, so plant growth in them should be possible in the future. Willows placed through the gabions into the backfill during construction at Rubicon Properties are doing well, as are willow bundles placed behind gabions prior to completion of backfilling.

Gutters and dikes are effective when rebuilt to form a bench at the toe of a steeply eroding slope, and frequently cost less than 25 percent of gabion or rock wall construction costs. Gutters and dikes also have fallen prey to snow plows and other types of heavy equipment and can only remain effective if protected by snow stakes and careful maintenance.

Willow Wattling. The pattern of growth and survival of willow wattling at Rubicon Properties points to the benefits of gathering and placing willow wattling when the plants are dormant or semi-dormant. Willows gathered in July, August and early September did not survive despite careful handling and regular irrigation. Willows gathered and placed in late September, May, and early June, while dormant or semi-dormant, have produced a profusion of shoots. Even though long term survival is still a matter of conjecture, correctly installed willow wattling provides a tremendous degree of mechanical soil stabilization even if the willow branches eventually die. Willow wattling considerably improves the opportunity for other types of plants to take root and grow.

Plantings. The Northstar shrub plantings resulted in better survival than has been the case with other plantings in the Tahoe Basin. This is probably due to the relatively good soil and gentle slopes which characterize most of the Northstar Plots. The top performers among the shrubs include several natives, *Chrysothamnus nauseosus*, *Purshia tridentata*, *Artemisia tridentata*, *Penstemon newberryi*, *Atriplex canescens*, and *Eriogonum umbellatum* and several exotics, *Caragana arborescens*, *Penstemon strictus*, *Salix gracilis*, and *Salix purpusea*.

Seeding. Among the grasses, two wheatgrasses, "Tegmar" and "Luna", proved outstanding. All herbaceous seeding plots were evaluated in late July 1977. Grass stands were rated on a relative scale from 1 to 10; with one indicating no seeding and ten indicating the best stand on the site. Evaluations were judgmental, rather than quantitative. The overall impression of the various treatments on the Rubicon site was that they were very similar. On the 1-10 scale, the maximum difference between treatment means was about 2 points. If this trend continues, then there will be no real differences between treatments, and the most cost effective methods will be those that are least expensive.

Some small treatment differences have been observed. The higher seeding rate (86 kg/ha) tends to produce a denser initial grass stand than the lower seeding rate (41 kg/ha). The additional seed is relatively inexpensive and therefore, may be justifiable. The higher wood fiber mulch rate (5600 kg/ha) produced a slightly better grass stand on the average than the lower mulch rate (2800 kg/ha). The additional mulch cost almost $900 per hectare; thus additional mulch may not be cost effective. Straw mulched plots produced slightly better initial grass stands on the average than the hydromulched plots.

Mulch remaining after the first winter and spring was also evaluated in July 1977. Results, expressed as percentage of plot still covered with mulch, are as follows:

wood fiber @ 2800 kg/ha	53%
wood fiber @ 5600 kg/ha	82%
straw @ 4500 kg/ha	55%[A]

The remaining straw mulch coverage for the different tackifiers was as follows:

wood fiber (1100 kg/ha) as tack	70%[B]
Ecology Control	50%
Dow XFS 4163-L	70%
Terratack II	50%
Terratack II Super Concentrate	40%

Future evaluations will yield more definitive results and possibly reveal the best method, or methods.

[A] Average coverage for all straw tackifier treatments.

[B] Wood fiber coverage includes ground covered by the wood fiber tackifier as well as ground covered by straw.

SECTION IX

INSTITUTIONAL PROCEDURES FOR EFFECTIVE EROSION CONTROL

Sufficient regulatory control now exists in California to insure that problems similar to Rubicon Properties can never develop in the future. The California State Water Resources Control Board (State Board) and the nine Regional Water Quality Control Boards (Regional Boards) have regulatory authority over the water resources of the State (62). As empowered by the laws of the State of California, one of the regulatory tools available to the State and Regional Boards is the establishment of waste discharge requirements. In addition to other types of pollutants, waste has also been defined to include "waste from construction activities". This has been interpreted in court to include eroded sediments resulting from improper construction methods. If waste discharge requirements established for a particular discharge are violated, then several alternatives are available to a Regional Board to force a discharger into compliance. Among them are:

- A time schedule for compliance with waste discharge requirements may be ordered by a Regional Board,
- A Cease and Desist Order requiring the discharger to comply with waste discharge requirements may be adopted by a Regional Board,
- A Cleanup and Abatement Order may be issued to the discharger requiring him to cease discharging waste in violation of waste discharge requirements and cleanup any waste discharged to the waters of the State.

Further violation of waste discharge requirements or any of the above orders may be referred to the Attorney General of the State to collect civil monitary remedies from the discharger for up to $10,000 per day, or to enjoin such activities as may be causing violation of waste discharge requirements.

In the case of the operation of wastewater treatment plants in California, the State and Regional Boards are not allowed to specify which treatment processes must be used to meet waste discharge requirements. However, unlike wastewater treatment plants, California Law (Water Code, Section 13360) permits the State and Regional Boards to describe specific methods which must be used to control eroding (or threatening to erode) waste earthen materials. Typical waste discharge requirements which may be applied by the Regional Board in the Lake Tahoe vicinity to current and proposed future construction projects which pose existing or threatened erosion problems are as follows:

A. General Waste Discharge Requirements

- The discharge of treated or untreated domestic sewage, industrial waste, garbage or other solid wastes, or any other deleterious material to surface waters is prohibited.

- The discharge, attributable to human activities, of solid or liquid waste materials, including soil, silt, clay, sand, and other organic and earthen materials, to surface waters is prohibited.

- The discharge, attributable to human activities, of solid or liquid waste materials, including soil, silt, clay, sand, and other organic and earthen materials, to lands within the highwater rim (Elevation 6229.1 ft. MSL) of Lake Tahoe or within the 100-year flood plain of any tributary to Lake Tahoe is prohibited.

- The discharge shall not cause a pollution.

- Neither the treatment nor the discharge of waste shall cause a nuisance.

- The discharge shall not cause any measurable color, odor, bottom deposits, floatable materials, oil, grease, or radionuclides to be present in any surface waters.

B. Specific Waste Discharge Requirements

1. Construction Drainage

- The transport of suspended sediment by drainage or surface flows from disturbed areas under construction to adjacent land areas or surface waters is prohibited.

- Adequate erosion control and sediment or surface flow containment facilities shall be constructed and maintained to prevent discharge of waste earthen material from disturbed areas under construction.

- There shall be no significant modification of existing drainage ways or existing stream channel geometry which would allow a discharge of sediments or eroded materials to adjacent properties in violation of other provisions of these requirements.

- Earthen berms or other sedimentation barriers shall be located downgradient from construction areas to prevent the discharge of earthen waste onto adjacent land areas or surface waters.

- Rock slope protection aprons shall be placed at the outlet of all culverts to prevent scour.

- All disturbed street surfaces shall be periodically sprinkled lightly and swept by a mechanical sweeper as necessary to prevent fine material from being discharged into drainage ways.

- The length of the open trench at the end of each working day shall not exceed 50 feet.

- Any damage or break in existing water lines shall be immediately repaired and measures must be immediately implemented to prevent erosion or sedimentation into any drainage way.

- Water discharged from any sewage or water facilities including water from testing lines shall be disposed of in such a manner as to not cause erosion or sedimentation or discharge of waste earthen materials into any drainage way.

2. Construction Waste

- The discharge of surplus or waste material including, but not limited to, soil, sand, silt, clay, or other earthen materials, to drainage ways is prohibited.

- The placement of waste earthen materials in such a manner as to allow the discharge of any portion of such materials to adjacent drainage ways is prohibited.

- There shall be no surplus or waste material, including soil, sand, silt, clay, or other earthen materials, placed in drainage ways.

- All loose piles of soil, silt, sand, clay, debris, and other earthen materials shall be protected in a reasonable manner to eliminate discharge to waters of the State.

- All surplus soil, silt, sand, clay, or other earthen materials shall be removed from the site after construction and deposited in a location so as to eliminate the sedimentation of surface waters.

- All rock riprap used for slope protection shall be cleaned of soil and carefully placed so as not to cause sedimentation or increased turbidity in surface waters.

- Materials used in dams, dikes, and levees used in creek crossings shall consist of sandbags filled with clean sand or other nonsilting materials.

- At all creek crossings, and whenever the natural bank of the river is disturbed, or where called for on the construction plans, rock riprap slopes protection shall be provided for erosion protection during high flows.

- Fresh concrete and cement shall not be allowed to enter surface waters.

3. Storm Runoff

- Effluent discharged from a grease trap/sedimentation basin shall not appear as surface flow, but must be infiltrated by a subsurface percolation bed, except for a greater than 1 hour 20-year storm.

- A maintenance program shall be established to ensure proper operation of the grease trap/sedimentation basin and subsurface percolation bed.

- Waste removed from the grease trap/sedimentation basin shall be disposed of in an approved manner.

- Drainage collection, retention, and infiltration facilities shall be constructed and maintained to prevent transportation of waste from areas of completed construction.

- Surface flows from the subject property shall be controlled so as to not cause downstream erosion at any point.

- Storm runoff from paved areas shall be diverted to percolation facilities on the project site.

- The infiltration trench system shall be installed around the perimeter of the site and shall be so designed such that any runoff in excess of the trench storage and percolation capacity is discharged to a storm drain.

- An oil and grease trap shall be installed in the storm drainage system immediately prior to discharge to the storm drain.

- Sheet flow of runoff shall be retained to prevent drainage concentrations.

- Suitably designed, gravel filled infiltration trenches are to be located under roof drip lines.

- Trenches at the edge of driveway and parking areas shall be cleaned periodically to remove grease and gasoline residues that may accumulate.

- Energy dissipators shall be provided where erosive velocities will occur.

- Cross ditches shall be installed and maintained on slopes where vegetation does not provide adequate soil stabilization.

4. Disturbed Areas

- There shall be no disturbance of natural vegetation or soil conditions except where erosion control measures can be installed and operational prior to October 15 of each year.

- There shall be no disturbance of natural vegetation or soil conditions between October 15 and May 1 of each year.

- Cut and fill slopes which may result from construction on the subject property shall be designed with slopes not exceeding two horizontal to one vertical.

- All nonconstruction areas shall be protected by barriers or fencing to prevent disturbance.

- Stream alteration areas and stream relocation areas shall be stabilized by the addition of rock slope protection as necessary, periods of no flow.

- Ephemeral stream relocation areas shall be flared at each downstream end to conform to existing stream patterns.

5. Revegetation

- Disturbed areas shall be adequately restabilized and the stabilization facilities shall be continually maintained.

- All cut and fill slopes, except predominantly rocky areas, shall be reseeded and/or revegetated with plants indigenous to the area. A cut and fill slope management program shall be implemented to ensure that all reseeded areas develop root systems sufficient to prevent erosion.

6. Effluent Limitations

- The discharge from the subject site shall not contain any perceptible floating material including, but not limited to solids, liquids, foams, and scums.

- The discharge from the subject site shall not contain oils, greases, waxes, or other hydrocarbon or petroleum derivative materials that cause visible film or coating on the surface of the receiving water or on objects in the receiving water.

- The discharge from the subject site shall not contain settleable substances in concentrations that may result in the deposition of material in any surface waters.

- The discharge from the subject site shall not have a pH value below 7.0 units nor greater than 8.4 units.

- The discharge from the subject site shall not contain substances in concentrations individually, collectively, or cumulatively toxic, harmful, or deleterious to humans, animals, birds, or aquatic biota, including, but not limited to, those substances specified in the California State Drinking Water Standards.

- All surface flows generated from the project site which are discharged to surface waters or storm drainage systems shall not contain constituents in excess of the following limits:

Constituent	Units	Mean[1/]	Maximum
Total Nitrogen (Nitrate & Kjeldahl)	mg/l-N	0.25	1.5
Total Phosphate	mg/l-P	0.02	0.1
Turbidity	FTU	3.0	20
Suspended Sediment	mg/l	25	80
Phenolic Compounds	mg/l	-	0.04
C.O.D.	mg/l	5	10
MBAS	mg/l	-	0.15
Apparent Color	c.u.	-	5

[1/] Arithmetic mean value of any ten (10) consecutive samples.

- If the water quality constituent levels of waters entering or passing adjacent to the subject property or any work area or waste producing facility within the subject property from upstream areas are of a superior or equal water quality to the numerical standards above, those waters shall meet the water quality constituent levels listed above prior to discharge from the property.

- If the water quality constituent levels entering the subject property or any work area or waste producing facility within the subject property exceed the numerical standards specified above, there shall be no more than a ten percent increase in the downstream value as compared to the upstream value.

7. Provisions

- The discharger shall comply with the Monitoring and Reporting Program and requirements established by the Regional Board.
- The discharger shall immediately notify the Regional Board by telephone whenever an adverse condition occurs as a result of this discharge; written confirmation shall follow.
- Any proposed material change in the character of the waste, method of disposal, increase of discharge, or location of discharge shall be reported to this Regional Board. This shall include all signifficant soil disturbances and stream channel modifications.
- The Regional Board reserves the privilege of changing all or any portion of the waste discharge requirements upon legal notice and after opportunity to be heard is given to all concerned parties.
- The owner of the property subject to waste discharge requirements shall be considered to have a continuing responsibility for ensuring compliance with applicable waste discharge requirements in the operation or use of the owned property. Any change in the ownership and/or operation of the property subject to waste discharge requirements shall be reported to the Regional Board. Notification of applicable waste discharge requirements shall be furnished the new owner(s) and/or operator(s). A copy of such notification shall be sent to the Regional Board.
- Surface waters, as used in this Order, include, but are not limited to, live streams, either perennial or ephemeral, which flow in natural or artificial water courses and natural lakes and artificial impoundments of waters within the State.

C. A Case History

The enforcement of the above waste discharge requirements for ongoing or future construction activities is relatively straightforward. An entity or person found to be in violation of waste discharge requirements may be enjoined, be forced to pay stiff monitary remedies, and/or receive a jail sentence. In the Lake Tahoe vicinity, the Regional Board is actively engaged in applying waste discharge requirements of the type listed above to new construction projects. Coupled with vigorous enforcement, waste discharge requirements have altered construction activities so that they produce even less severe erosion and sediment related pollution problems than the low levels found at Northstar (less than a one fold increase above natural background levels). Certainly, there will never be future developments which have such severe erosion and sediment control problem as are found within the Rubicon Properties Subdivision.

With present and future construction related erosion and sediment problem well under control, the remaining problem is to control erosion and sediment pollution generated by past construction activities. Erosion control at Rubicon Properties is an excellent example of the types of problems which are encountered in controlling erosion in past developments. The original developer of Rubicon Properties has long since sold all interest in the development. Most likely he cannot be held accountable for the poor planning, construction, and development practices exhibited there. The only potentially responsible parties are the several hundred hapless individual landowners within the development and the County. The following chronology of events is a brief description of the attempts that were made to control erosion problems within Rubicon Properties.

In 1970, the California Regional Water Quality Control Board, Lahontan Region (Lahontan Regional Board) established waste discharge requirements on the County and over 200 privately owned parcels within Rubicon Properties Subdivision, Unit No. 2 (upper portion) (63). This was the initial formal attempt to coerce the County and the landowners into correcting the massive erosion problems that existed there. Replies were received from over 50 percent of the landowners, all of which stated, to the effect, that their individual holdings were not contributing to the erosion problems. Furthermore, the landowners requested that they no longer be described as "dischargers". Without lengthy court proceedings, it would have been difficult cult to prove that they were dischargers and were responsible for the erosion problems. The County, although remiss in accepting the Subdivision in the first place, was unable to proceed because of a lack of funds and knowledge concerning effective erosion control.

By 1971, the Lahontan Regional Board adopted an interim basin water quality control plan which formally established the following beneficial uses for the waters of the Lake Tahoe Basin (64):

- Domestic supply
- Agricultural supply
- Water contact recreation
- Nonwater contact recreation
- Scientific study
- Fresh water habitat
- Fish spawning

To protect the beneficial uses, the interim basin furthermore established several waste discharge prohibitions, including:

- The discharge of solid or liquid materials, including soil, silt, clay, sand, and other organic and earthen materials, to Lake Tahoe or any tributary thereto.

- The discharge of solid or liquid waste materials, including soil, silt, clay, sand, and other organic and earthen materials, to lands below the highwater rim of Lake Tahoe or within the 100-year flood plain of any tributary to Lake Tahoe.

The threatened discharge of solid or liquid waste materials, including soil, silt, clay, sand, and other organic and earthen materials, due to the placement of said materials below the highwater rim of Lake Tahoe or within the 100-year flood plain of any tributary to Lake Tahoe.

In 1972, the Lahontan Regional Board proceeded with an intensive water quality investigation within Rubicon Properties. The purposes of this investigation were twofold (1) to determine the overall extent of the erosion problem, and (2) to determine the principle sources of eroded sediment within the Subdivision. The investigation determined that the roadway cuts and fills adjacent to county maintained roadways and extending onto many private parcels, were primarily responsible for the massive sediment load of Lonely Gulch Creek. Although unable to quantify the annual sediment load at that time, the Lahontan Regional Board substantiated the large reduction in insect species populations and diversity within the Creek. It was concluded that erosion from the development was the principle reason for the observed reductions in aquatic life.

In 1973, the County retained the services of a consultant to determine what procedures should be employed at Rubicon Properties to correct the erosion problems (65). In addition, all major erosion problems were identified within the Lake Tahoe Basin portion of the County and ranked as to degree of severity. Rubicon Properties, Unit No. 2, was ranked as the number one priority problem. The total cost of erosion control of all problems within the County was identified to be $1.5 million. The cost to solve the problems within Rubicon Properties, Unit No. 2, was estimated at $218,089.

In 1974, The Lahontan Regional Board issued a second set of waste discharge requirements naming the County as the sole responsible party for the correction of the erosion problems within Rubicon Properties (66). October 1, 1975, was identified as the date by which all required erosion control work must be completed. However, arguments were put forward by the County that insufficient funds existed to correct the problems at Rubicon Properties. Even though specific erosion control recommendations were made by the consultant, the County also felt that insufficient knowledge existed to guarantee success if the proposed control measures were implemented. As a result, no enforcement actions were taken by the Lahontan Regional Board and matters appeared to have reached a state of impasse. Injunctions against the results of past construction activities are meaningless and civil monetary suits against public entities, such as the County, are difficult to obtain and frequently accomplish very little.

In 1975, the Lahontan Regional Board adopted a plan which updated and replaced the interim basin plan (67). Additional water quality objectives were established for Lake Tahoe, including specific objectives for Lonely

Gulch Creek. Also in 1975, the upper portion of Rubicon Properties within the Lonely Gulch Creek watershed was identified as an erosion and sediment control site as part of this erosion control project by the State Board. Until this time, very little had been done to control erosion at Rubicon Properties beyond normal maintenance activities. However, because additional funds were available to supplement their resources, the County readily agreed to assist the State Board in demonstrating a variety of erosion control techniques. Prior to 1975, the County had invested approximately $11,500 per year at Rubicon Properties, primarily for cleanup and maintenance activities. However, once additional funds were assured from outside sources, the County expended the equivalent of $65,000 in county manpower and equipment to assist the State Board in correcting erosion problems at Rubicon Properties. This was spent during the 15-month period from July 1975 through September 1976. The erosion control measures which were implemented at the Rubicon Properties as a result of this erosion control project are fully described in Section VI and Appendices A and B.

Summary

Ample controls exist to insure that current and future construction activities will provide sufficient erosion control. The control of erosion from past activities, although ample regulatory control exists, requires a substantial capital investment. For the most part, these capital investments must be made by public agencies, as exemplified by the situation at Rubicon Properties. The erosion control project has demonstrated that effective erosion control does not have to be exorbitantly expensive and, if pre-control maintenance costs are high, may be amortized in a relatively short period of time (12.5 years or less in the case of the Rubicon Properties project site) through local maintenance cost savings. However, the rapidity at which erosion control problems generated in the past may be corrected can only be rapidly accelerated if the resources of the directly responsible local entity are supplimented by assistance from other interested public or private contributors. The assistance could easily take the form of labor, equipment, materials, or monitary contributions. As exemplified by the chronology of events surrounding erosion control at Rubicon Properties, without a certain degree of outside assistance, remedial erosion control of past mistakes in rapidly developed areas, such as Lake Tahoe, will be an extremely time-consuming if not impossible process.

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APPENDIX A

PLANT PROPAGATION FOR THE REVEGETATION OF ROAD CUTS AND FILLS IN THE LAKE TAHOE BASIN

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APPENDIX A

Plant Propagation for the Revegetation of Road Cuts and Fills in the Lake Tahoe Basin

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1. Introduction

Highway cuts and fills in the Lake Tahoe Basin often are slow to establish vegetation cover or do not establish such cover at all. The soils and subsoils of this area are subject to extreme erosion when devoid of vegetation because of the course textured soil types, periods of heavy water run-off, frost heaving and wind action. This erosion is detrimental to streams and lakes in the Lake Tahoe Basin, causes costly road maintenance work, endangers property and people and is aesthetically objectionable.

A 3½ year study for the California Department of Transportation (CalTrans) completed in 1974 has shown that it is possible to revegetate these difficult sites with combinations of mechanical stabilization and revegetation using native plant species. The time and financial restraints of this project were such that only a portion of the potentially useful native plant spectrum were tested in adequate quantities and several possible techniques of mechanical and vegetative stabilization were either not evaluated or were evaluated in a limited way. Although much was learned about the propagation, culture establishment of native plant materials on these difficult sites, the usable plant spectrum is limited by our present knowledge. Survival and growth of those species tested in quantity (e.g. Arctostaphylos nevadensis, pine mat manzanita; Artemisia tridentata, big basin sagebrush; Ceanothus prostratus, squaw carpet; Purshia tridentata, Antelope brush; and Penstemon newberryi, mountain pride) might be enhanced by better cultural practices which would, for example, permit development of better root systems. A number of species were evaluated in very limited quantities (e.g. Symphoricarpos acutus, creeping snowberry; Lonicera conjugialis, double-fruited honeysuckle; Chrysothamnus nauseosus, rabbit brush; Arctostaphylos patula, green leaf manzanita; Cercocarpus ledifolius, curl leaf mountain mahogany; Rhamnus rubra, Sierra coffeeberry; and Spiraea densiflora, mountain spiraea) because of limited resources, difficulty of propagation and growth, or lack of propagating material (i. e. seeds, cuttings). Many of these show promise of being very useful if propagation and cultural practices can be solved. A number of other species which, in their native habitat, show a wide range of adaptation to microenvironment and inherent ability to stabilize bare soils were not evaluated due to poor seed production during the course of this project or difficulties in propagation or culture. These include *Prunus emarginata*, bitter berry; *Querus vaccinifolia*, huckleberry oak; *Nama lobbii*, woolly nama; *Castanopsis sempervirens*, bush chinquapin; *Ceanothus cordulatus*, mountain whitehorn; *Lupinus* spp., lupine; and *Rubus parviflorus*, thimbleberry. These should be studied in great detail in order to effectuate a more thorough representation of the vegetation in the Tahoe Basin.

Still other potentially valuable revegetation species were not evaluated due to time and financial restraints of the project or because sufficient observations of their potential were not made in the early portions of this project. Some examples are *Rosa woodsii* var. *ultramontana*, mountain rose; *Symphoricarpos vaccinoides*, mountain snowberry; *Lonicera caurina*, mountain fly honeysuckle; *Lonicera involucrata*; *Ribes divaricatum* var. *inerme*; *Ribes montigenum*, mountain gooseberry; *Ribes roezlii*, Sierra gooseberry; *Ribes cereum*, squaw currant; *Ribes viscosissimum*, sticky currant; *Ribes nevadense*, mountain pink currant; *Ceanothus velutinus*, snowbrush; *Holodiscus microphyllus*, littleleaf cream bush; *Amelanchier pallida*, Western service-berry; and *Amelanchier pumila*, smooth service-berry. The *Salix* spp. (other than *Salix lemmonii*, lemon willow) should be investigated. These should include studies of relative rootability and performance of several species, if funding permits. Certain herbaceous genera would also warrant exploration, such as *Eriogonum* spp. and *Lupinus* spp., Lupines.

Additional research on propagation, culture and establishment of methods for species of proven revegetation potential, of species evaluated only in limited trials and on species not included in earlier research would provide a plant spectrum from which to choose the best species for virtually any microsite in the Lake Tahoe Basin or other similar habitats.

2. Objectives

The objectives were to:

1. Survey study sites, evaluate physical and microenvironment conditions and select potentially useful species for revegetation.

2. Research propagation and cultural practices to produce the required plant spectrum. Specific studies to be made of seed versus cutting propagation, growing media, depth of containers, irrigation and nutritional needs (in the nursery) and timing of propagation. These studies will provide 10-20,000 plants, depending on level of funding, for revegetation. Additional plants will be obtained from the California Division of Forestry.

3. Assist State Water Resources Control Board in planning, restoration and planting which will be done by California Conservation Corps, County or Water Board personnel.

4. Collect data on growth and survival and monitor overall success of plantings.

5. Special attention was to be paid to the establishment of greater vegetation density at the top of highway cuts.

3. Soil Mixes

In an attempt to improve survivability of the plants for this demonstration project, different soil mixes were used. Standard U.C. mix was used as a control and comparison for two test mixes. The U.C. mix consists of 1:1:1 ratio of sand, peat and ammoniated redwood sawdust. The other two mixes used were 1:1 peat-vermiculite and 1:1 peat-basalite. Basalite is a granular clay material which is a manufacturing by-product. Basalite must be leached to remove excessive boron before it is incorporated in a planting mix. Both test mixes had the following nutrients supplied per standard six inch pot; 8g dolomite, 2g oyster shell, 2g superphosphate, 3g potassium nitrate. The criteria used to determine the desirability of each mix will be the percentage of plants surviving at the end of the observation period.

4. Containers

Four types of containers were used to compare growth and transplant survival of several species.

The standard container used for all species unless otherwise noted was a commerical peat pot(1,2) 6.25 cm diameter by 7.5 cm deep.

Two sizes reusable, tapered, deep plastic tubes(1,3) were used. One was 7.5 cm diameter X 23.75 cm deep. The other was 1.9 cm in diameter X 13.75 cm deep.

"Book" planters(1,4), ribbed plastic folders with 4 (four) planting compartments, each 3.75 cm X 3.75 cm X 11.9 cm, were the fourth type of container. Because of the thin plastic used, these are usually not reusable.

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1) No endorsement is implied. Commercial names are given for identification purpose only.
2) Jiffy Pot #425.
3) Manufactured by Crown Zellerbach Corp., Edwood Nursery, Araura, Ore.
4) Hillson's Rootainers, Spencer-Lemaire Ind. Ltd., Edmonton, Alberta, Canada

5. Growing Conditions

Greenhouse temperatures were usually 18°C days, 13°C nights but sometimes greenhouses were used with 21 or 24°C day temperature and 16 or 18°C nights.

Sweatbox conditions for propagation were plastic covered frames with 21°C bottom heat located in a lathhouse.

Intermittent mist was on a 5 sec. every 2.5 min. (on a greenhouse bench) with bottom heat (24°C). Both tap water and deionized (DI) water mists were used. Tap water was used unless DI is specified.

6. Plant Materials
Principal Species Investigated

Plant materials grown in larger quantities are listed alphabetically first. Species grown in smaller quantities are discussed later.

Agropyron trichophorum ('Luna' pubescent and 'Topar' pubescent wheatgrasses):

Seeds were sown directly in peat pots the first week of April in greenhouses (18°C day, 13°C nights). Flats were covered with newspaper for about 5 (five) days until the seeds began to germinate. Plants were ready to plant out approximately 6 (six) weeks after sowing.

Artemisia caucasica (Caucasica artemisia):

Cuttings were taken from stock plants in June and rooted in small tubes under mist. One hundred cuttings were stuck in the mixes previously described. The total rooting after six weeks was 83% (250/300). There was no recorded difference in rooting between the soil mixes. The rooted cuttings were ready to plant 10-12 weeks after being stuck.

Artemisia tridentata (Big basin sage):

Seeds were stratified at 2°C for ten days before being sown in flats in the mist. This seed, which had been in cold storage for three years, germinated within three weeks. The seedlings were transplanted approximately 5 (five) weeks after the sowing date to small tubes with the soil mixes listed previously. The plants were grown in the greenhouse another two months and in the lathhouse for six weeks before being moved to the planting site. Survival data are given in Table A-1.

Table A-1. *Artemisia tridentata*
Survival in 3 soil mixes, 3½ months after transplanting.

Soil Mix	Number Planted	Survival #	Survival %
U. C. Mix	40	36	90.0
Peat-basalite	40	39	97.5
Peat-vermiculite	40	38	95.0

Atriplex gardneri (Gardner valley saltbush):

Seed which had been in cold storage for four years was sown in flats on a greenhouse bench on 1-27-76. Within a week the first seeds began germinating. Seedlings were transplanted within a month (2-20-76) of the sowing date to the containers and in the soil mixes listed previously. After approximately three months growth in the greenhouse the plants were placed in the lathhouse. In two months (five months from sowing) the plants were moved to the planting site. Survival data at that time were given in Table A-2. There were no consistent differences in survival which could be attributed to container size or soil mix.

Table A-2. *Atriplex gardneri*
Survival in various soil mixes and container types, 5 months after transplanting.

Soil Mix	Container	Number Planted	Survival #	Survival %
UC Mix	small tube	100	92	92.0
Peat-basalite	small tube	100	89	89.0
Peat-DG*	small tube	100	87	87.0
UC Mix	peat pot	40	38	95.0
Peat-basalite	peat pot	40	36	90.0
Peat-DG*	peat pot	40	32	80.0
UC Mix	book	40	38	95.0
Peat-basalite	book	40	39	97.5
Peat-DG*	book	40	39	97.5

*DG = field collected decomposed granite.

Cornus stolonifera (Creek dogwood):

Cuttings were originally collected in the spring from plants in the field. These were rooted and used for stock plants.

Succulent tip cuttings from stock plants rooted 100% within two weeks. Rooted cuttings grew rapidly in peat pots and were ready to plant out 6-8 weeks after sticking.

Lupinus spp. (Lupines):

Small lots of lupine seed had been collected in previous years and had been in cold storage for varying number of years. Most of the seed was not identified as to species. Hot (73°C) water was poured over the seeds and they were allowed to soak in the cooling water. Unimbibed seed were separated and treated as above with boiling water. Still unimbibed seed were separated and boiled one minute before soaking 24 hours in the cooling water. Imbibed seeds were sown in flats, covered with newspapers and placed on a greenhouse bench. Germination began after about five days. At the second leaf stage the seedlings were transplanted to peat pots. They were moved to the lathhouse after two weeks and outside two weeks later. After about two weeks outside they were ready to plant.

Considerable additional research on lupine propagation, bacterial inoculation, direct seeding and transplanting is being done by Mr. David Gilpin as his master's thesis project. Results of these studies are not yet available.

Penstemon newberryi (Mountain pride):

Dormant cuttings were taken from field grown plants in the late fall and early winter of 1975-76. The cuttings were dipped in 1000 mg/l IBA for 1-2 seconds and stuck in vermiculite in outdoor sweat boxes. One flat of cuttings that was stuck 12-17-75 had 98% (173/176) rooting after two months. Of seven flats stuck 1-13-76 to 1-30, 87% (1187/1349) had rooted by 3-22-76. Most of these cuttings had good top growth and could have been transplanted at least a month earlier. These rooted cuttings were randomly planted in the three mixes described previously and in three containers: deep tubes, small tubes, and 7 cm peat pots. There were nine replications of 13 plants per treatment in a complete block arrangement. The plants were grown in the greenhouse two weeks, the lathhouse two weeks and then outside in partial shade until they were transported to the site. Large, well rooted *P. newberryi* cuttings such as these, would reach suitable planting size in about one month in the small tubes, two months in the deep tubes and about a month and a half in the peat pots.

After four to five months growth in the containers survival (Table A-3) was highest in the deep tubes (346/351) next in the small tubes (336/351) and least in the peat pots (307/351). The plants in the vermiculite peat mix had the highest survival (335/351), in regular U.C. mix next (330/351) and the least survival in the basalite peat mixture (324/351). These differences are small and probably of no real significance. Survival data one year after planting should be compared.

Table A-3. *Penstemon newberryi*
Survival in 3 containers and 3 soil mixes, July & August, 1976
13 planted/treatment/rep.

		MIX						
		U.C. MIX		PEAT/VERMICULITE		PEAT/BASALITE		CONTAINER TOTAL
	Rep. #	7/13	8/4	7/13	8/4	7/13	8/4	UC PV PB
DEEP TUBE	1	13	12	13	13	13	13	
	2	13	13	13	13	13	13	
	3	12	12	13	13	13	13	
	4	13	13	12	12	12	12	
	5	13	13	13	13	12	12	
	6	13	12	13	13	13	13	
	7	13	13	13	13	13	13	
	8	13	13	13	13	13	13	
	9	13	13	13	13	12	12	230/232/228
TOTALS		116	114	116	116	114	114	690
SMALL TUBES	1	13	13	13	13	12	12	
	2	13	13	10	10	13	13	
	3	13	13	13	13	12	12	
	4	13	13	12	12	12	12	
	5	13	13	13	13	13	13	
	6	9	9	12	11	13	13	
	7	13	13	13	13	12	12	
	8	13	13	13	12	13	13	
	9	13	13	13	13	11	10	226/222/221
TOTALS		113	113	112	110	111	110	669
PEAT POTS	1	12	11	12	12	12	12	
	2	12	12	12	12	13	13	
	3	12	12	11	11	10	9	
	4	12	12	12	12	12	11	
	5	7	7	13	13	11	11	
	6	13	13	13	13	11	11	
	7	11	11	10	10	10	9	
	8	9	8	11	11	8	7	
	9	13	13	13	13	12	12	200/214/194
TOTALS		101	99	107	107	99	95	608
GRAND TOTALS		330	326	335	333	324	319	1967

Four to six weeks after transplanting these first cuttings, additional cuttings were taken from them. These softwood (but not succulent) cuttings were dipped in 1000 ppm IBA for 1-2 seconds and rooted under deionized (DI) intermittent mist. Three hundred (300) cuttings were rooted in vermiculite and 300 cuttings were stuck directly in small tubes, 100 of each of the three mixes previously described. They were left 10 days in DI mist, cycle 2.5 sec. every 2.5 min. and ten days on the hardening off bench. Rooting was 100% in all cases. The cuttings rooted in vermiculite were then transplanted on one of the three previously described mixes in 7.5 cm peat pots. All cuttings were left in the greenhouse ten days and them moved to the lathhouse. Thirty days after sticking, roots were protruding from the bottoms of the small tubes and the root ball held together although the tops were the sides of the peat pots. After another ten days to two weeks (total time, six weeks) in the lathhouse the direct stuck plants were ready to plant while those that were transplanted required another two weeks in the lathhouse (summer conditions in Davis).

Prunus emarginata (Bitter cherry):

Many propagation techniques have been tried with this species with very limited success. Dormant hardwood cuttings in the sweatbox and leafy simihard wood cuttings under mist have failed to root. Root cuttings send up shoots but do not initiate new roots. These shoots were excised from the root cuttings, dipped in 4000 mg/l IBA and rooted under mist about 7% (4/60) of the excised cuttings rooted within three weeks, but four weeks after sticking all cuttings were dead.

Field collected root suckers have rooted somewhat more successfully. Suckers were taken (on 4-18-76 at approximately 5000 ft. elevation) before they emerged from the ground. These were rinsed in 1:9 clorox solution and dipped in 4000 ppm IBA for 1-2 seconds. They were then stuck (4-23-76) in U.C. mix in two container sizes, with the top of the cutting just below the soil surface. The containers were placed on a greenhouse bench. In gallon cans there was no rooting. Cuttings stuck in deep tubes showed, Table D-4, 30% (12/40) rooting and survival after two months (6-22-76).

Leafy root suckers (taken 5-17 and 22-76 at approximately 1500 meter elevation) were dipped (5-31-76) in 4000 mg/l IBA and stuck in deep tubes up to the former ground level on the cutting. Cuttings just beginning to show green were held in the hardening-off mist bench (2.5 sec. every 2.5 min) for two weeks before being moved to the greenhouse. Five weeks after sticking (7-8-76) they showed 40% (8/20) rooting and survival. Cuttings with more leaves were placed in the mist bench two weeks and the hardening off mist bench for two weeks before being moved to the greenhouse. Two months after sticking (7-29-76) they showed 6% (3/40 and 2/40) rooting and survival. These were limited trials but show that propagation by root sucker is a definite possibility for this species.

Preliminary research on germination of Prunus emarginata seeds was done in early 1976. Comparisons were made between hot and cold water pre-soaking and three stratification regimes: 21°C, constant; 7°C constant and a fluctuating regime of one month at 3°C and four months at 1°C. The results are shown in Table A-5.

Table A-4. Rooting of _Prunus emarginata_ root suckers under various conditions.

Treatment*	Container	Date Taken	No. Rooted	%
Greenhouse	1 gallon	4/19/76	0	0
Greenhouse	Deep tubes	4/19/76	12/40	30
Hardening off 2 wk.	Deep tubes	5/17 & 22	8/20	40
Mist 2 wk.	Deep tubes	5/17 & 22	3/40	7.5
Hardening off 2 wk.			2/40	5

*All were dipped in 4000 mg/1 for 1-2 sec. before sticking.

Table A-5. Response of _Prunus emarginata_ seeds to hot and cold water pre-soaking and three stratification regimes.

	Hot Water			Cold Water		
	Stratification					
Week	21°C	3°-1°C	7°C	21°C	3°-1°C	7°C
0*	0	11	0	7	10	10
1	2	9	2	9	10	10
2	5	1	1	0	2	1
3	2	1	0	1	1	2
4	0	1	0	1	0	1
5	3	4	3	0	1	1
6	0	3	2	2	2	0
7	12	3	2	2	2	2
Total	24	33	10	22	27	27
Grand Total		67			76	
Grand totals			21°C	3°-1°C	7°C	
Stratification			46	60	37	

*Germination when removed from stratification.

Hot water does not appear to be more effective than cold for soaking the seeds and temperature during germination appears unimportant although the experiment was not done in such a way that statistical analysis could be used on the results.

The higher germination with the fluctuating temperatures was the basis of further tests in 1976-77.

More work was done on germination of Prunus emarginata seeds in 1976-77. The seeds have a hard enacarp which may somewhat restrict uptake of water. They also appear to have an internal dormancy which can be broken by a period of moist stratification. To try to overcome these factors, seed of P. emarginata were soaked in deionized water for two or eight days and then stratified in moist vermiculite for five to five and a half months at four different temperatures (A and B) constant 7°C (C and D) constant 1°C (E and F) 7°C for one month and then 1°C for four months or (G and H) 15°C for one month and then 1°C for four months. These seeds had been in cold storage for four years. The highest germination of 14% (22/150) was obtained with an eight-day soak followed by one month stratification at 7°C and four month stratification at 1°C. The seeds were germinated in the dark at 21°C on moist filter paper in petri dishes. Radical elongation was counted as germination. This data is summarized in Table A-6.

The seeds were planted in three different containers. They grew 100% (40/40) in deep tubes, 90% (54/60) in small tubes and 77% (31/40) in peat pots (see Table A-7).

Purshia tridentata (Antelope bitterbrush):

Three treatments were tried on small lots of Purshia tridentata seeds. Those stratified in moist vermiculite at 2°C for 19 days (3-4-76 to 3-23-76) and germinated under mist had 93% (28/30) germination within two weeks. (Table A-8). Seeds from the same seed lot which had been soaked 24 hours in Gibberellic acid about 60% (18/30) germinated which was slower and more erratic than the germination of the stratified seed. These seeds had been in cold storage for about four years. Freshly purchased seeds treated with 3% thiourea for five minutes as per seeds of woody plants of the United States, had only 2% (2/100) germination.

Ribes roezlii (Sierra gooseberry):

Fall collected seeds of this species were stratified in moist vermiculite at 7°C for three months (10-7-75 to 1-12-76). Half of the seeds were sown in 1:1 peat/perlite and half in 1:1 perlite/vermiculite. Since the seeds were very small and mixed with debris they were not counted. After two weeks in the mist, there were three seedlings in the vermiculite and one in the peat. Two weeks later there were three more in the peat. None of the seedlings made any further growth and all died shortly.

In mid-May, 1976, a small number (30) of field collected succulent tip cuttings were taken. These were dipped in 2000 mg/l IBA for 1-2 seconds, stuck in vermiculite, and placed in the mist. There was no rooting. Due

Table A-6. Response of *Prunus emarginata* seeds to soaking times and temperature during stratification. Fall, 1976. Totals for 6 replicates of 25 seeds each.

Treatment	No. Germinating per Week						Total		Germination During Stratification
	1	2	3	4	5	6	No.	%	%
A. 2-day soak-7°C strat	0	0	0	0	0	0	0/150	0	1
B. 8-day soak-7°C strat	4	0	0	0	0	0	4/150	2	5
C. 2-day soak-1°C strat	3	0	1	2	0	0	6/150	4	2
D. 8-day soak-1°C strat	3	0	0	1	0	0	4/150	2	2
E. 2-day soak-7°C& 1°C strat	2	1	0	0	0	0	3/150	2	3
F. 8-day soak-7°C& 1°C strat	7	8	0	2	2	2	21/150	14	7
G. 2-day soak-15°C & 1°C strat	3	0	0	0	0	2	5/150	3	3
H. 8-day soak-15°C & 1°C strat	3	2	0	2	0	2	9/150	6	2
Summary Totals									
A. & B. 7°C strat	4	0	0	0	0	0	4/300	2	
C. & D. 1°C strat	6	0	1	3	0	0	10/300	3	
E. & F. 7°C & 1°C strat	9	9	0	2	2	3	25/300	8	
G. & H. 15°C & 1°C strat	6	2	0	2	0	4	14/300	5	
A, C, E & G 2-day soak	8	1	1	2	0	2	14/600	2	
B, D, F, & H 8-day soak	17	10	0	5	2	5	34/600	7	
GRAND TOTAL	25	11	1	7	2	7	53/1200	4	

Table A-7. Survival of *Prunus emarginata* seedlings in 3 containers. Spring, 1977.

Containers	Mean No. Surviving	Sx	%
Peat pots - 2 replications of 20 each	15.5	2.1	77
Small tubes - 3 replication of 20 each	18.0	1.0	90
Peep tubes - 2 replications of 20 each	20.0	0.0	100

Table A-8. *Purshia tridentata* seed response to several pre-germination treatments. Spring 1976.

		# Seed Germinated					
Treatment	#planted	Wk. 1	Wk.2	Wk.3	Wk.4	Wk.5	Final %
Stratified 19 days @ 2°C	30	25	28	28	28	28	93
50 mg/1 GA, 24 hrs.	30	5	9	15	16	18	60
3% Thiourea 5 minutes	100	1	2	2	2	2	2

to the low spreading habit of this species and its ubiquity in dry rocky places more work should be done toward propagating it.

Ribes viscosissimum (Sticky currant):

Fall collected seeds of this species (tentatively identified as *Ribes viscosissimum*) were stratified for five months in moist vermiculite at 7°C. They were sown on a flat and placed in the mist for two weeks. Germination was fair and six weeks after sowing the seedlings were transplanted to 7.5 cm peat pots. Tip cuttings taken from the seedlings in early June (four months after sowing) rooted 100% under mist and grew so rapidly that cuttings could be made from them within six weeks.

Salix spp. (Varous Willow species):

Dormant cutting material of *Salix lemmonii* (Lemmon willow) and *S. lasiandra* (western block willow) was collected from the field in early December, 1975, and kept in cold storage until the hardwood cuttings were made. The four-inch long cuttings were stuck in flats of vermiculite and placed in unheated cold frames in a lathhouse by mid-January, 1976. Rooted cuttings were transplanted into deep tubes and peat pots with UC mix within four months of the sticking date.

Observations were made on the rooting ability as it related to the diameter of the cuttings and as it was affected by a hormone dip (1000 mg/1 IBA for one minute). In general, for both species, the large diameter cuttings (1.25 cm to 1.9 cm) had a higher rooting percentage (see Table A-9) than the medium (1.0 cm to 1.25 cm) or the small (0.6 cm) diameter cuttings. Cuttings of both species dipped in the IBA had a lower rooting percentage than those not treated with the hormone.

Cutting material of four species, *S. rigida*, Brittle willow, *S. lasiandra*, Western black willow, *S. scouleriana*, Scouler's willow, *S. lemmonii*, Lemmon willow, was collected in mid-December, 1976, from sites at the south end of the Tahoe Basin. Cuttings were made during the two days following the

Table A-9. Effect of hormone and cutting diameter on rooting of Salix lemmonii and S. lasiantra.

Salix lemmonii

Cutting Diameter	HORMONE TREATMENT No IBA	%	1000 mg/l IBA	%	Total	%
0.6 cm-small	22/30	73.3	12/30	40.0	34/60	56.7
1.0 cm - 1.25 cm - medium	29/30	96.7	16/30	53.3	45/60	75.0
1.25 cm - 1.9 cm - large	29/30	96.7	17/30	56.7	46/60	76.7
Total	80/90	88.9	45/90	50.0		

Salix lasiandra

Cutting Diameter	HORMONE TREATMENT No IBA	%	1000 mg/l IBA	%	Total	%
0.6 cm - small	19/30	63	15/30	50	34/60	56.7
1.0 cm - 1.25 cm - medium	28/30	93	18/30	60	46/60	76.7
1.25 cm - 1.9 cm - large	27/30	90	24/30	80	51/60	85.0
Total	74/90	82.2	57/90	63.3		

collection from the field, and stuck on the third day. The cutting diameters, media, and rooting environments were the same as in 1975.

The results did not have the same consistent pattern as in 1975-76 where the larger diameter cuttings had a higher rooting percentage than the medium or smaller diameters. Generally, there were higher rooting percentages on cuttings not dipped in 1000 mg/l IBA than those that were given a one minute dip.

S. scouleriana in all treatments had considerably lower percentages of rooting. This species was the slowest to root and to make new growth. The new leaves were infected with insect galls that were treated with Isotox. There was more noticeable growth after two sprays of Isotox two weeks apart. Well rooted cuttings (roots 5-10 cm long) were transplanted to containers during the first week of March (approximately three months after sticking). Transplanted cuttings grown in the lathhouse in deep tubes could fill the container in 2 to 2½ months (= early to mid-May).

Symphoricarpus acutus (Creeping snowberry):

In mid-May, 1976 a small number of softwood cuttings were taken from stock plants of this species. The cuttings were dipped in 2000 mg/l IBA for 1-2 seconds and then stuck in vermiculite. About 95% of the cuttings rooted within three weeks under mist but all dropped their leaves. When transplanted most of the cuttings failed to resprout and all died.

7. Plant Materials
Other Species Investigated

Very limited propagation trials were conducted on a number of other species. Some of these should be good candidates for revegetation of disturbed sites and further work is warranted. The trials were limited by both time and financial constraints and often by the availability of seed or cutting material. Brief summaries of these trials follow.

Amelanchier alnifolia (Western serviceberry):

Seeds were stratified at 7°C for three months. Of 48 seeds that germinated, 24 plants survived to planting size stock.

Arctostaphylos patula (Greenleaf manzanita):

This species has been more difficult to root than A. nevadensis. More work is needed on both species. Rooting of the latter species has been variable from year to year and for cuttings from different location. It may be that variables in microsite (soils, rainfall, etc.) may have a strong influence on rooting. This hypothesis should be tested by growing stock plants under controlled conditions of irrigation and fertility.

Atriplex canescens (Four-winged saltbush):

Seeds sown directly in peat pots on February 10, 1977 produced good planting stock under greenhouse conditions in two months. Plants need cutting back if held in these conditions more than two months. It is recommended that 5-7 seeds be sown per pot and these be thinned to one seedling per pot at an early age.

Castanopsis sempervirens (Bush chinquapin):

Viable seed was unobtainable during 1975-1976. Dormant cuttings calloused heavily but only four plants of over 50 cuttings rooted. This indicated that it is possible to root the species but better treatments need to be developed. Cutting back stock plants to force juvenile growth and the use of softwood cuttings should be investigated.

Ceanothus cordulatus (Mountain whitethorn):

Trials with both seeds and dormant cuttings were essentially unsuccessful with less than 0.1% success. This species is widespread in California mountains. Additional work with fresh seed from different sources is warranted. Softwood cuttings should be tried also.

Table A-10. *Salix spp*. Comparison of rooting of several species of *Salix* as influenced by cutting diameter and hormone treatment.

S. rigida:

Treatment*	Replications			Total		-IBA	%	+IBA	%
1	6	7	9	22	small	23/30	76.7	22/30	73.3
2	9	7	7	23	medium	28/30	93.3	22/30	73.3
3	9	5	8	22	large	29/30	96.7	14/30	46.7
4	10	8	10	28					
5	7	5	2	14					
6	10	9	10	29					

S. lasiandra:						-IBA	%	+IBA	%
1	7	10	8	25	small	28/30	93.3	25/30	83.3
2	9	9	10	28	medium	26/30	86.7	21/30	70.0
3	8	6	7	21	large	28/30	93.3	25/30	83.3
4	8	9	9	26					
5	9	8	8	25					
6	8	10	10	28					

S. scouleriana:						-IBA	%	+IBA	%
1	5	5	0	10	small	7/30	23.3	10/30	33.3
2	1	2	4	7	medium	14/30	46.7	11/30	36.7
3	2	6	3	11	large	9/30	30.0	8/30	26.7
4	4	4	6	14					
5	1	4	3	8					
6	1	4	4	9					

S. lemmonii:						-IBA	%	+IBA	%
1	8	8	4	20	small	16/30	53.3	20/30	66.7
2	4	7	5	16	medium	25/30	83.3	22/30	73.3
3	7	9	6	22	large	25/30	83.3	24/30	80.0
4	9	9	7	25					
5	7	7	10	24					
6	9	7	9	25					

	Treatments					
Total Species:	1	2	3	4	5	6
S. rigida	22	23	22	28	14	29
S. lasiandra	25	28	21	26	25	28
S. scouleriana	10	7	11	14	8	9
S. lemmonii	20	16	22	25	24	25

*Treatments:
1. 0.6 cm dia. + 1000 mg/l IBA
2. 0.6 cm dia., no IBA
3. 1.0 cm - 1.25 cm dia. + 1000 mg/l IBA
4. 1.0 cm - 1.25 cm dia., no IBA
5. 1.25 cm - 1.9 cm dia., + 1000 mg/l IBA
6. 1.25 cm - 1.9 cm dia., no IBA

Chrysothamnus nauseosus (Rabbit brush):

This species is easy to grow by direct sowing about ten seeds per pot and thinning to one or two plants after germination. One problem that must be recognized is that in some years, early fall frosts when the plant is in flower, result in a crop of non-viable seed.

Eriogonum unbellatum (Sulphur flower):

Cuttings under mist (March 1977) all rotted. The use of a sweat box should be tried with this species.

Seeds were sown directly in several sized containers, 3-6 seeds per container and covered with newspaper. Seed was of poor quality with many hollow (aborted seeds). Of 574 containers, over 450 had at least one seedling. Seedling propagation is rapid and good plants can be produced in three to four months.

Holodiscus bousieri (Cream bush):

No cuttings of this plant rooted when taken as dormant cuttings. Softwood cuttings should be tried in June.

Lonicera conjugialis (Double-flowered honeysuckle):

A limited quantity of seed was available. These were stratified for three months at 7°C. Of 64 which germinated only 20 survived transplanting and the subsequent growing period. Cultural conditions (media, container size, etc.) need more investigations.

Penstemon strictus (Rocky Mountain penstemon):

This penstemon rooted well from cuttings. Other species of penstemon native to the Sierras should also be tried.

Rhamnus rubra (Sierra coffeeberry):

Three months stratification at 7°C resulted in good germination. Of 296 seedlings transplanted, 284 survived to transplanting size. This is a good candidate for revegetation. Cutting propagation of dormant wood was unsuccessful. However, softwood cuttings of this species are being used by commericial nurseries.

Ribes cereum (Squaw currant):

A limited number of seeds were stratified for four months at 7°C. At the end of stratification 24 were germinated. Twenty of these survived to planting size. The remainder of the seeds were sown and an additional 40 plants resulted.

Ribes nevadensis (Sierra currant):

Stratification for six months at 7°C resulted in good germination. A shorter stratification period (perhaps 3-4 months) probably would be adequate because nearly 300 seeds had germinated while being stratified. Dormant cuttings rooted well but survival after transplanting was poor. Softwood cuttings should be tried.

Rosa woodsii var. ultramontana (Mountain rose):

A small number of seeds were stratified for five months at 7°C. Thirty-six seeds germinated. A cutting propagation trial using dormant wood of two diameters and several hormone levels (324 cuttings) did not produce any rooted plants. This is surprising in view of the ease of rooting of most species of roses. Softwood cuttings should be tried in June or July.

Rubus parviflorus (Thimble berry):

This species is an invader of highway cuts and talus slides in some parts of the basin. Limited trials with both softwood and dormant cuttings have not been very successful. The genus Rubus generally roots well with some species rooting whenever a tip touches the ground. Because of its potential for revegetation additional research is warranted. One approach would be the use of root cuttings.

Sambucus microbotrys (Red elderberry):

This species roots readily from softwood cuttings and no new research was conducted on the propagation of it.

8. Outplantings

The plant materials were delivered to the site as needed. Planting was done, for the most part by State Board crews. Because U.C. personnel were not on site during all planting operations, mapping of plantings was largely the responsibility of the State Board personnel. Planting locations are summarized in Appendix B.

A large planting of Penstemon newberryi was done by U.C. personnel. This experiment was to compare field survival of this species which had been grown in different media and container sizes. Description of the media and container sizes is at the beginning of this report.

Data was to have been taken in May-June of 1977. Due to the lateness of the growing season and the covering of many plants by the soil material, valid counts could not be made prior to the termination date. This species has the ability to survive some burial and grow through it. This survival data species which were delivered to and planted at the Rubicon Properties erosion control project site is given in Table A-11. Plantings were conducted in the summer and early fall of 1976 (5,876 plants) and the spring of 1977 (14,484 plants).

TABLE A-11

INVENTORY OF PLANT MATERIALS DELIVERED TO RUBICON PROPERTIES EROSION CONTROL PROJECT SITE

Delivered Summer 1976

Species	7-13	7-27	8-4	8-11	8-23	Total by Species
Arctostaphylos nevadensis	8	1		31		40
Artemisia caucasica		5			250	255
Artemisia tridentata	31	11	82			124
Atriplex gardneri		490				490
Ceanothus prostratus			133	131		264
Composite (Purple)				4		4
Composite (Yellow)		122		64		186
Cornus stolonifera	14			10	12	36
Grasses (assorted sp)	320	160	420	1208		2108
Lupinus spp.	72	64	77			213
Penstemon newberryi	448	139	761	130	360	1838
Prunus emarginata	19					19
Purshia tridentata	21	21		31		73
Ribes viscosissimum	24			54	18	96
Symphoricarpus acutus	5				124	129
Nama lobbii		1				1
Total	962	1014	1473	1663	764	5876

Delivered Spring 1977

Species	Container	5-11	5-23	6-3	6-20	Total by Container & Species	Total by Species
Amelanchier alnifolia	book	24		10		34	34
Arctostaphylos nevadensis	gallons	5				5	5
Arctostaphylos patula	peat pots			105	6	111	124
	deep tubes			10		10	
	gallons	2				2	
Artemisia tridentata	peat pots			24	75	99	99
Atriplex canescens	peat pots		400			400	1135
	books		568			568	
	small tubes		110			110	
	deep tubes		22	35		57	

Table A-11.
Inventory delivered Spring 1977 (Con't):

Species	Container	5-11	5-23	6-3	6-20	Total by Container & Species	Total by Species
Castanopsis sempervirens	deep tubes			1		1	1
Ceanothus cordulatus	books			2		2	15
	deep tubes				13	13	
Ceanothus prostratus	peat pots		120	64	70	254	1362
	books	156	84	640		800	
	small tubes			100		100	
	deep tubes	125				125	
	gallons			3		3	
Chrysothamus nauseosus	peat pots	456	75	125	30	686	686
Cornus stolonifera	deep tubes		39			39	39
Erigonium umbellatum	peat pots		126	42	8	176	421
	books		175			175	
	small tubes		70			70	
Lonicera conjugialis	peat pots			2		2	24
	books	20		2		22	
Lupinus breweri	peat pots	36				36	116
	books				50	50	
	deep tubes				30	30	
Lupinus fulcratus	peat pots	36				36	126
	books				50	50	
	deep tubes				40	40	
Lupinus grayi	peat pots	37				37	112
	books				50	50	
	deep tubes				25	25	
Lupinus sellulus	peat pots	37				37	102
	books				50	50	
	deep tubes				15	15	
Luna pubescens	peat pots	1760	380	40		2180	4052
	books	672	960	240		1872	
Penstemon newberryi	peat pots	720	265	53		1038	2707
	books	84			100	184	
	small tubes		930	180		1110	
	large tubes	360	15			375	

Table A-11.
Inventory delivered Spring 1977 (Con't):

Species	Container	5-11	5-23	6-3	6-20	Total by Container & Species	Total by Species
Penstemon stricta	peat pots	80		88		168	264
	books	92				92	
	gallons			4		4	
Prunus emarginata	peat pots	4	38	135	410	587	1352
	books	8		165	450	623	
	large tubes	75		5		80	
	gallons	3	23	26	10	62	
Purshia tridentata	peat pots		35	73		108	1008
	books			500		500	
	small tubes			300		300	
	large tubes			100		100	
Rhamnus rubia	books	284		20		304	304
Ribes cereum	books	20		35		55	60
	deep tubes			5		5	
Ribes nevadensis	peat pots	3		2	150	155	155
Ribes roezlii	peat pots	6	7	1		14	15
	deep tubes				1	1	
Ribes viscosissimum	gallons			1		1	1
Rosa woodsia	peat pots			30		30	30
Rubus parviflorus	peat pots	12	1	1		14	14
Salix spp.	books				48	48	57
	deep tubes			9		9	
Symphoricarpus spp.	books		65			65	65
Total by date		5117	4508	1378	1681		14484

9. Summary

Advice to project personnel on planning and site preparation was accomplished in 1976 by several trips to the site by the principal investigator during the spring and summer. It was not possible to take spring survival data by the termination date of the project because of the unusually late spring. Plants which were partially buried and some deciduous material could not have been counted with any degree of validity as late as the week of June 20, 1977.

There is much additional information on procedures and plant materials for revegetation in the Tahoe Basin in:

> "Revegetation of Disturbed Soils in the Tahoe Basin"
>
> Andrew T. Leiser, James J. Nussbaum, Burgess Kay,
> Jack Paul, William Thornhill
>
> Final Report, March 1971 - June 1974
> CA-DOT-TL-7036-1-75-24
>
> Sponsoring Agency:
> California Department of Transportation
> Transportation Laboratory, Sacramento, Calif.

Scheduling of plant production is detailed in part under the various plant species section of the report. The plant species vary in the length of time required to produce stock suitable for out-planting. Longer growing time is required to produce adequate root systems in the deeper containers. A summary of several production schedules with examples of species which might be grown in each is as follows. Dates given are *lead time* prior to planting.

Seed Production-Slow Growing Species

	Greenhouse Production	Field Production
Seed Collection:	Summer-Fall-12-8 mo.	Summer-Fall, 24-16 mo.
Stratification:	Winter, 8-6 mo.	Winter, 16-14 mo.
Germination, Transplanting:	Late Winter, 6-4 mo.	Late Winter, 14-12 mo.
Growing-on:	Spring, 4-2 mo.	Spring-Summer, 12-10 mo.

The field production will produce larger plants, 4" to "gallon" can size and will be higher in cost for the "gallon"-can size.

Examples: *Prunus emarginata*, *Ribes* spp., *Penstemon* spp., *Ceanothus* spp. etc. (the more woody spp. for the most part).

Seed Production-Rapid Growing Species

	Greenhouse Production	Field Production
Seed Collection:	Summer-Fall, 12-8 mo.	Summer-Fall, 12-8 mo.
Stratification:	Non required for most.	
Germination:	4-3 mo.	5-4 mo.
Growing on:	3-2 mo.	4-3 mo.

Examples: Grass sp., *Atriplex* spp., *Artemisia* spp., *Chrysothamum nauseosus*, *Eriogonum umbellatum*, *Purshia tridentata*, *Lupinus* spp. (Herbaceous, suffrutescent and rapid-growing woody species for the most part).

Cutting Production

Soft-wood Cuttings-Outdoor Stock Plants

Take cuttings: May-July, 12-10 mo.

Rooting: May-Aug., 12-9 mo.

Growing on: June-Fall and Late Winter-Early Spring

Finished plants: April-through Summer

Soft-wood Cuttings-Greenhouse Stock Plants

Take cuttings: Jan-March, 6-3 mo.

Growing on: Feb.-June, 5-2 mo.

Finished plants: May through Summer

Examples: Easy to root species, eg. *Penstemon*, *Salix* etc.

Dormant Cuttings

Take cuttings: Sept.-November, 10-7 mo.

Rooting: Requires 1-4 mo. depending on species

Growing on: (Greenhouse in colder months)
2-5 mo.
Note: If grown out-of-doors and/or larger plants are required, one full growing season is required and lead time becomes 22-19 mo.

10. Costs

Production of plants for revegetation involves three basic steps. 1) Seeding or collecting and preparing cuttings, 2) rooting the cuttings, or germinating the seed, 3) transplanting the seedlings or rooted cuttings to containers and growing them to large enough size for outplanted. The following discussion and tables presents the costs associated with each of these steps. The final table gives the total cost of producing plants for revegetation.

These cost estimates include some of the many variables which affect plant production. The factors include difficulty of collecting cuttings, size of cuttings, percentage rooting, rooting time, type of container and time required to grow to size.

Seeding

	Unit Cost
Seed cost per unit is very small. Unit cost includes direct seeding and thinning to desired number per pot.	$ 0.03

Collecting and Preparing Cuttings

Cost of collecting cuttings in the Tahoe Basin from Davis, California:

2 man-days @ \$8.00/hr.	\$128.00
1½ days per diem @ \$35.00	52.00
Mileage, 500 km. @ 0.9	45.00
Supplies: ice, bags, labels	3.00
	\$228.00

Number of cutting collected in one trip varies from 5,000 to 10,000 depending upon ease of collection.

Collection Unit Cost:	High (5,000/trip)	\$ 0.045
	Low (10,000/trip)	0.023
Preparing and sticking cuttings		0.03
Materials cost: media and pro-rata flats		
Preparation Unit cost:	Large cuttings @ 100/flat	0.015
	Small cuttings @ 150/flat	0.010

Summary of Cutting Collection and Preparation Costs

	Low Cost	High Cost
Cost of collecting cuttings	\$0.023	\$ 0.045
Cutting preparation	0.030	0.030
Material large cuttings	0.015	0.015
Small cutting	0.010	0.010
TOTAL Large cuttings	0.068	0.090
Small cuttings	0.063	0.085

Rooting Cuttings

The unit cost of rooting a cutting depends on the propagation space required and the weeks required for adequate rooting.

Costs are based on 35 cm X 55 cm X 8.75 cm flats, prorated for the life of the flat. One medium, vermiculite (not reusable) is used as an average cost. Large cuttings @ 100/flat are about 538 cuttings/sq. meter. Small cuttings @ 150/flat are about 807 cuttings/sq. meter. Figures are given for two propagation environments, a greenhouse mist requiring four or six weeks for rooting and a lathhouse sweatbox requiring eight or twelve weeks for rooting.

Table A-12. Total Cost of Rooted Cuttings ($)

Environment	Greenhouse Mist				Lathhouse Sweatbox			
Rooting Time	4 Weeks		6 Weeks		8 Weeks		12 Weeks	
Cost of Collecting Cuttings	Low	High	Low	High	Low	High	Low	High
A. LARGE CUTTINGS								
Cost, stock cutting	.068	.090	.068	.090	.068	.090	.068	.090
Propagation space/maint.	.025	.025	.037	.037	.030	.030	.045	.045
TOTAL: 100% Yield	.093	.115	.105	.127	.098	.120	.113	.135
80% Yield	.116	.144	.131	.159	.122	.150	.141	.169
60% Yield	.155	.192	.175	.212	.163	.200	.188	.225
40% Yield	.232	.288	.263	.318	.245	.300	.283	.338
B. SMALL CUTTINGS								
Cost, stock cutting	.063	.085	.063	.081	.063	.085	.063	.085
Propagation space/maint.	.017	.017	.025	.025	.020	.020	.030	.030
TOTAL: 100% Yield	.080	.102	.088	.110	.083	.105	.093	.115
80% Yield	.100	.128	.110	.138	.104	.131	.116	.144
60% Yield	.133	.170	.147	.183	.138	.175	.155	.192
40% Yield	.200	.255	.220	.275	.208	.263	.233	.288

Growing Costs

The following are costs associated with transplanting rooted cuttings to containers, and growing cuttings or seedlings up to a usable size. The following basic costs are used in the calculations.

Greenhouse space and maintenance-	$13.45/sq. meter	2/Mo.
Lathhouse space and maintenance-	8.07/sq. meter	2/Mo.
Medium (potting mix)		
Sand @ $7.85/cubic meter =	2.00	
Ammonized Redwood Sawdust- @ $3.50/cubic meter	7.00	
Peatmoss two bales @ $8.00	16.00	
Fertilizers	2.00	
Labor, steam sterilizing	20.00	
	$47.00	

Cost per Cubic Meter $18.81

Containers[1]	Cost/100 Units	Estimated Reuse	Net Cost/100 Units
Peat Pots[2]	$2.64	No	$2.64
Books[3]	3.75	No	3.75
Large tube[4]	18.75	5X	3.75
Small tubes[4]	3.75	5X	.75

Total Production Cost

The total cost of producing plants for revegetation can be calculated from the preceding tables. The total cost of producing direct seeded container plants can be calculated by adding the seeding cost ± $.03 per plant to the growing cost in Table A-13. The total cost of producing plants from cuttings can be calculated by adding the cost of a rooted cutting from Table A-12 to the growing cost from Table A-13. Note, however; that large cuttings cannot be transplanted into the small tubes.

Discussion

In our tests, the 7.5 cm deep peat pots have been used for all species. Growth is this particular design which is 1.25 cm deeper than the standard 6.25 cm peat pot has been generally good. The greater depth is superior to the shallow peat pot for the native plant spectrum. Some problems of drying out are encountered when plants are moved to the field.

---

1. No endorsement is implied. Commercial names are given for identification purposes only.
2. Jiffy Pot #425.
3. Hillson's rootainers, four compartments each, Spencer-Lemaire, Inc. Ltd., Edmonton, Alberta, Canada.
4. Tubes, large,
        small, in block of 100 units.
   Crown Zellerbach Corp., (Ed Wood Nursery) Aurora, Oregon.

TABLE A-13

Growing Cost Summary - Unit Cost

Container	Greenhouse		Greenhouse
	3 Months	6 Months	3 Mo., Lath 3 Mo.
Peat Pot [1,2]	$0.23	$0.41	$0.34
Books [1,3]	0.15	0.21	0.18
Tube, large [1,4]	0.26	0.45	0.37
Tube, small [1,4]	0.04	0.06	0.05

Range of Total Production Costs

	High		Low
Direct seeding	$0.07	-	$0.48
Large cuttings	$0.50	-	$0.79
Small cuttings	$0.12	-	$0.74

The deep tubes require a longer growing period to obtain adequate root systems than do the peat pots or books. The large tube is more difficult to plant because of its depth. More work is required on cultural practices with the 1.9 cm tube to determine which species perform well in them. Many cuttings are too large to transplant into them. They have been very good for *Penstemon newberryi* where unrooted cuttings are stuck directly into them and then rooted.

The books have been very satisfactory. A larger sized book is available for larger plants. Costs of some larger sized books would be comparable to the large tube in terms of soil used, growing space etc.

APPENDIX B

EROSION CONTROL PLOT DESCRIPTIONS

Number		Page

FIGURES

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B-1	SCS Seedings and Plantings, 1973 - 1974, Northstar	281
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B-3	Herbaceous Seedings and Woody Plantings, 1976, Rubicon Properties	300
B-4	Shrub and Tree Plantings, 1977, Rubicon Properties	318

TABLES

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B-1	SCS Shrub Plot Descriptions, 1973 - 1974, Northstar.....	282
B-2	SCS Herbaceous Plot Descriptions, 1973 - 1974, Northstar	286
B-3	Revegetation Plot Descriptions, 1975 - 1976, Northstar .	291
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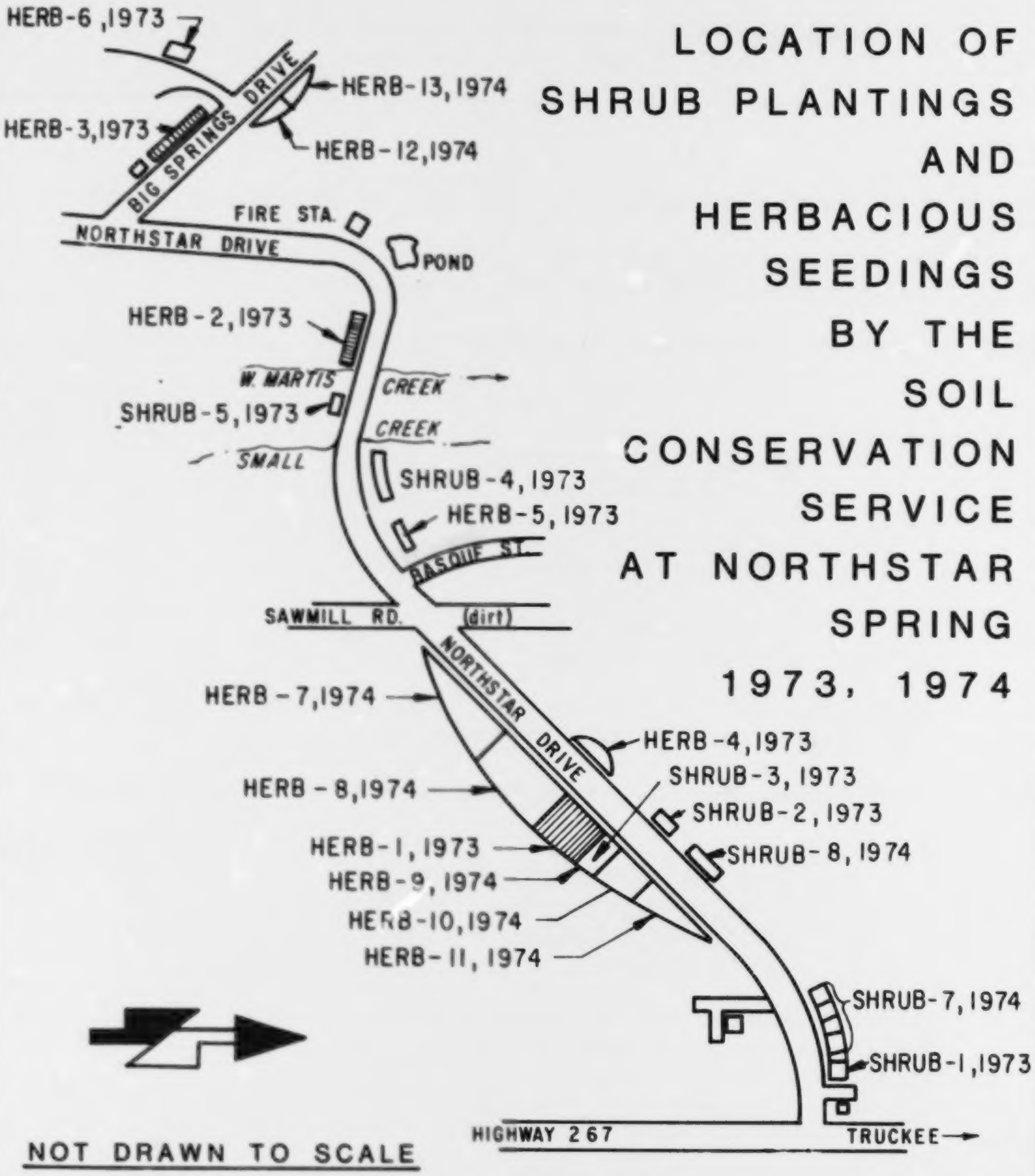
B-5	Plot Description Symbols For Interpretation of Tables B-3 and B-4	313
B-6	Shrub and Tree Plantings Section Descriptions, 1976, Rubicon Properties	319

LOCATION OF SHRUB PLANTINGS AND HERBACIOUS SEEDINGS BY THE SOIL CONSERVATION SERVICE AT NORTHSTAR SPRING 1973, 1974


HERB-6, 1973
HERB-13, 1974
HERB-3, 1973
HERB-12, 1974
BIG SPRINGS DRIVE
FIRE STA.
NORTHSTAR DRIVE
POND
HERB-2, 1973
W. MARTIS CREEK
SHRUB-5, 1973
CREEK
SMALL
SHRUB-4, 1973
HERB-5, 1973
BASQUE ST.
SAWMILL RD.
(dirt)
NORTHSTAR DRIVE
HERB-7, 1974
HERB-4, 1973
SHRUB-3, 1973
HERB-8, 1974
SHRUB-2, 1973
HERB-1, 1973
SHRUB-8, 1974
HERB-9, 1974
HERB-10, 1974
HERB-11, 1974
SHRUB-7, 1974
SHRUB-1, 1973
HIGHWAY 267
TRUCKEE

NOT DRAWN TO SCALE

NOTE:
HERBACIOUS SEEDING RATE - 45 KG/HECTARE
WOOD FIBER MULCH RATE - 1350 KG/HECTARE
16-20-0 FERTILIZER RATE - 560 KG/HECTARE

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

SCS SEEDINGS AND PLANTINGS

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY	FIGURE NUMBER B-1

TABLE B-1

SOIL CONSERVATION SERVICE TEST SHRUB PLANTING PLOT DESCRIPTIONS
SPRING 1973, 1974 - NORTHSTAR

PLOT NO.

SHRUB 1: South facing cut adjacent to sales office. Planted Spring 1973.

150 *Ceanothus prostratus*; 30 vertical rows, 5 plants/row, 2 ft. spacing, 70 survived until 1975, 63 until 1977.

SHRUB 2: Northwest fill facing. Planted Spring 1973.

# Planted		Survival	
		1974	1977
10	*Chrysothamnus nauseosus*	(8)	(8)
10	*Ceanothus prostratus*	(5)	(3)
10	*Ceanothus prostratus*	(4)	(2)
10	*Arctostaphylos patula*	(5)	(1)
10	*Arctostaphylos uva-ursi*	(4)	(0)
10	*Artemisia caucasia*	(1)	(1)
7	*Eriogonum umbellatum*	(7)	(6)*
10	*Penstemon strictus*	(9)	(8)*

Note: Spacing is 1.0 meter, 8 vertical rows. Rows listed left to right facing slope from Northstar Drive.

SHRUB 3: North facing cut across from Plot No. SH-2. Planted Spring 1973.

# Planted		1974	1977
6	*Caragana arborescens*	(6)	(6)
6	*Caragana arborescens*	(6)	(6)
7	*Myrica pennsylvanica*	(0)	(0)
7	*Syringa vulgaris*	(4)	(4)

Note: Spacing is 1.5 meter, 2nd and 3rd rows are 2.0 meters apart. Vertical rows listed from left to right facing fill from road surface.

SHRUB 4: North facing fill near small creek. Spring 1973.

# Planted		1974	1977
5	*Ceanothus prostratus*	(2)	(1)
5	*Chrysothamnus nauseosus*	(3)	(3)
5	*Chrysothamnus nauseosus*	(3)	(2)
4	*Chrysothamnus nauseosus*	(2)	(2)

* Reseeding and spreading profusely

TABLE B-1 continued

SHRUB 4:

# Planted		Survival 1974	Survival 1977
5	*Artemisia tridentata*	(5)	(5)
5	*Artemisia tridentata*	(5)	(5)
5	*Artemisia tridentata*	(4)	(3)
3	*Caragana arborescens*	(2)	(2)
2	*Artemisia tridentata*	(2)	(2)
5	*Atriplex canescens*	(2)	(1)
5	*Atriplex canescens*	(2)	(1)
5	*Ceanothus cordulatus*	(5)	(4)
4	*Ceanothus cordulatus*	(3)	(4)
5	*Caragana arborescens*	(3)	(2)
5	*Juniperus conferta*	(4)	(1)
5	*Kochia prostrata*	(1)	(1)
4	*Arctostaphylos patula*	(3)	(3)
5	*Penstemon newberryi*	(5)	(3)
5	*Penstemon newberryi*	(4)	(3)
5	*Purshia tridentata*	(5)	(5)
5	*Purshia tridentata*	(5)	(5)
5	*Purshia tridentata*	(5)	(5)
2	*Purshia tridentata*	(1)	(1)
5	*Rhus trilobata*	(1)	(0)
5	*Rhus trilobata*	(0)	(0)
4	*Rosa woodsii (cut)*	(4)	(3)
5	*Rosa wichuriana*	(5)	(4)
5	*Salix gracilis*	(5)	(5)
5	*Salix purpurea*	(5)	(5)

Note: Spacing 1.22 meter, 28 vertical rows. Rows listed right to left facing slope from Northstar Drive.

SHRUB 5: South facing fill near West Martis Creek. Spring 1973.

# Planted		1974	1977
10	*Ceanothus prostratus*	(0)	(0)

Note: 1.0 meter spacing, 2 vertical rows.

SHRUB 6: Northeast facing cut on Big Springs Drive. Spring 1973.

# Planted		1974	1977
6	*Ceanothus prostratus*	(2)	(?)
5	*Ceanothus prostratus*	(2)	(?)
4	*Artemisia tridentata*	(3)	(?)

Note: 3 vertical rows, rows 1 and 2 plants are 1.0 meter apart, row 3 plants are 1.2 meter apart. Rows listed left to right facing cut from road surface.

TABLE B-1 (continued)

SHRUB 7: South facing cut near Northstar entrance. Spring 1974.

	# Planted		Survival 1977
A.	4	Artemisia tridentata	(1)
	3	Ceonothus velutinus	(0)
	5	Chrysothamnus nauseosus	(0)
	3	Eriogonum umbellatum	(3)
	7	Artemisia tridentata	(2)
	5	Penstemon newberryi	(0)
	1	Arctostaphylos nevadensis	(0)
B.	4	Penstemon newberryi	(0)
	2	Artemisia tridentata	(2)
	1	Arctostaphylos nevadensis	(0)
	3	Ceanothus cordulatus	(0)
	5	Penstemon newberryi	(0)
	2	Eriogonum umbellatum	(2)
C.	5	Artemisia tridentata	(0)
	5	Penstemon newberryi	(0)
	1	Arctostaphylos nevadensis	(0)
	2	Ceanothus velutinus	(0)
	5	Chrysothamnus nauseousus	(0)
	3	Ceanothus velutinus	(0)
	3	Ceanothus cordulatus	(0)
D.	10	Penstemon newberryi	(1)
	1	Arctostaphytos nevadensis	(0)
	3	Erigonum umbellatum	(3)
	8	Artemisia tridentata	(2)
	5	Ceanothus consulatus	(0)
	2	Ceanothus velutinus	(1)
	1	Quercus vaccinifolia	(1)

Note: Parts A, B, C planted in horizontal rows as listed. Part D planted at random. See location map.

SHRUB 8: Northwest facing fill adjacent to Northstar Drive. Spring 1974.

	# Planted		1974	1977
A.	5	Penstemon strictus	(4)	(1)
	5	Penstemon strictus	(4)	(1)
	5	Penstemon strictus	(5)	(4)
	5	Arctostaphylos uva-ursi	(2)	(1)
	5	Rosa woodsii	(4)	(3)
	5	Rosa woodsii	(4)	(4)
	5	Cornus stolonifera	(2)	(2)

TABLE B-1 (continued)

SHRUB 8 (continued):

			Survival	
	# Planted		1974	1977
A.	5	*Cornus stolonifera*	(1)	(1)
	5	*Ephedra viridis*	(2)	(0)
	5	*Penstemon strictus*	(5)	(5)
B.	5	*Atriplex nuttalli*	(3)	(0)
	5	*Ephedra viridis*	(2)	(0)
	5	*Ephedra viridis*	(3)	(0)
	5	*Arctostaphylos uva-ursi*	(2)	(2)
	5	*Rosa woodsii*	(4)	(5)
	5	*Eleagnus angustifolia*	(?)	(0)
	5	*Eleagnus angustifolia*	(?)	(0)
	5	*Penstemon strictus*	(5)	(5)
	5	*Penstemon strictus*	(5)	(5)

Note: Parts A and B planted in horizontal rows as listed. See location map.

TABLE B-2

SOIL CONSERVATION SERVICE TEST HERBACEOUS SEED PLANTING
PLOT DESCRIPTIONS
SPRING 1973, 1974

HERBACEOUS SEEDING RATE: 45 kg/hectare
WOOD FIBER MULCH RATE: 1,350 kg/hectare
16-20-0 FERTILIZER RATE: 560 kg/hectare

PLOT NO.

HERB 1: Northwest facing cut on Northstar Drive. Spring 1973. Subplots A through L left to right in 3.0 meter widths.

Singles

		%
A.	*Agropyron trichophorum* (Luna pubescent wheatgrass)	100
B.	*Agropyron intermedium* (Tegmar intermediate wheatgrass)	100
C.	*Agropyron smithii* (Western wheatgrass)	100
D.	*Agropyron cristatum* (Fairway crested wheatgrass)	100
E.	*Poa ampla* (Sherman big bluegrass)	100
F.	*Agrostis tenuis* (Highland Colonial bent grass)	100
G.	*Agropyron riparium* (Sodar streambank wheatgrass)	100
H.	*Festuca ovina duriuscula* (Durar hard fescue)	100

Mixtures

		%
I.	Sodar streambank wheatgrass	30
	Pomar Orchardgrass	30
	Durar hard fescue	30
	White Dutch clover	10
J.	Tegmar intermediate wheatgrass	30
	Western wheatgrass	20
	Manchar smooth brome	20
	Sherman big bluegrass	20
	Rambler alfalfa	10
K.	Luna pubescent wheatgrass	30
	Fairway crested wheatgrass	20
	Sherman big bluegrass	20
	Latar orchardgrass	20
	Cicar Cicer milkvetch	10
L.	Fairway crested wheatgrass	20
	Pomar orchardgrass	20
	Sodar streambank wheatgrass	10
	Durar hard fescue	10

TABLE B-2 (continued)

HERB 1 (continued):

Mixtures	%
Sherman big bluegrass	10
Cicar Cicer milkvetch	10
White Dutch clover	10
Rambler alfalfa	10

Note: Each single or mixture type planted in 3.0 meter wide plots left to right facing cut from road surface.

HERB 2: South facing fill adjacent to Northstar Drive and West Martis Creek. Spring 1973.

Same single and mixture application as listed for HERB 1, planted left to right facing fill slope from road surface. Six meter blank spacing between single types E and F and mixture types I and J.

HERB 3: Northeast facing cut adjacent to Big Springs Drive. Spring 1973.

Same single and mixture application as listed for HERB 1, planted left to right facing cut slope form road surface. Mixture M was also included at right most end of HERB 3:

		%
M.	Purshia tridentata	50
	Atriplex canescens	50

HERB 4: Southeast facing cut adjacent to Northstar Drive. Spring 1973.

	%
Fairway crested wheatgrass	20
Pomar orchardgrass	20
Sodar streambank wheatgrass	10
Durar hard fescue	10
Sherman big bluegrass	10
Cicar Cicer milkvetch	10
White Dutch clover	10
Rambler alfalfa	10

HERB 5: Northwest facing fill adjacent to Northstar Drive. Spring 1973.

Same mixture application rate as listed for HERB 4.

TABLE B-2 (continued)

HERB 6: East facing cut slope adjacent to parking lot near Big Springs Drive. Spring 1973.

	%
Cana Reed canarygrass	30
Luna pubescent wheatgrass	40
Yellow sweetclover	10
Cicar Cicer milkvetch	10
Cascade broadleaf trefoil	10

HERB 7: Northwest facing cut slope adjacent to Northstar Drive. Spring 1974.

	%
Western wheatgrass	30
Pomar orchardgrass	30
Durar hard fescue	20
Blando brome	10
Lutana Cicer milkvetch	10

HERB 8: Northwest facing cut slope adjacent to Northstar Drive. Spring 1974.

	%
Sodar streambank wheatgrass	30
Pomar orchardgrass	30
Durar hard fescue	20
Blando brome	10
Lutana Cicer milkvetch	5
White Dutch clover	5

HERB 9: Northwest facing cut slope adjacent to Northstar Drive. Spring 1974.

Same herbaceous seed mixture as used in HERB 8.

HERB 10: Northwest facing cut slope adjacent to Northstar Drive. Spring 1974.

	%
Luna pubescent wheatgrass	30
Standard crested wheatgrass	10
Blando bromegrass	10
Sherman big bluegrass	20
Palestine orchardgrass	20
Lutana Cicer milkvetch	10

TABLE B-2 (continued)

HERB 11: Northwest facing cut slope adjacent to Northstar Drive. Spring 1974.

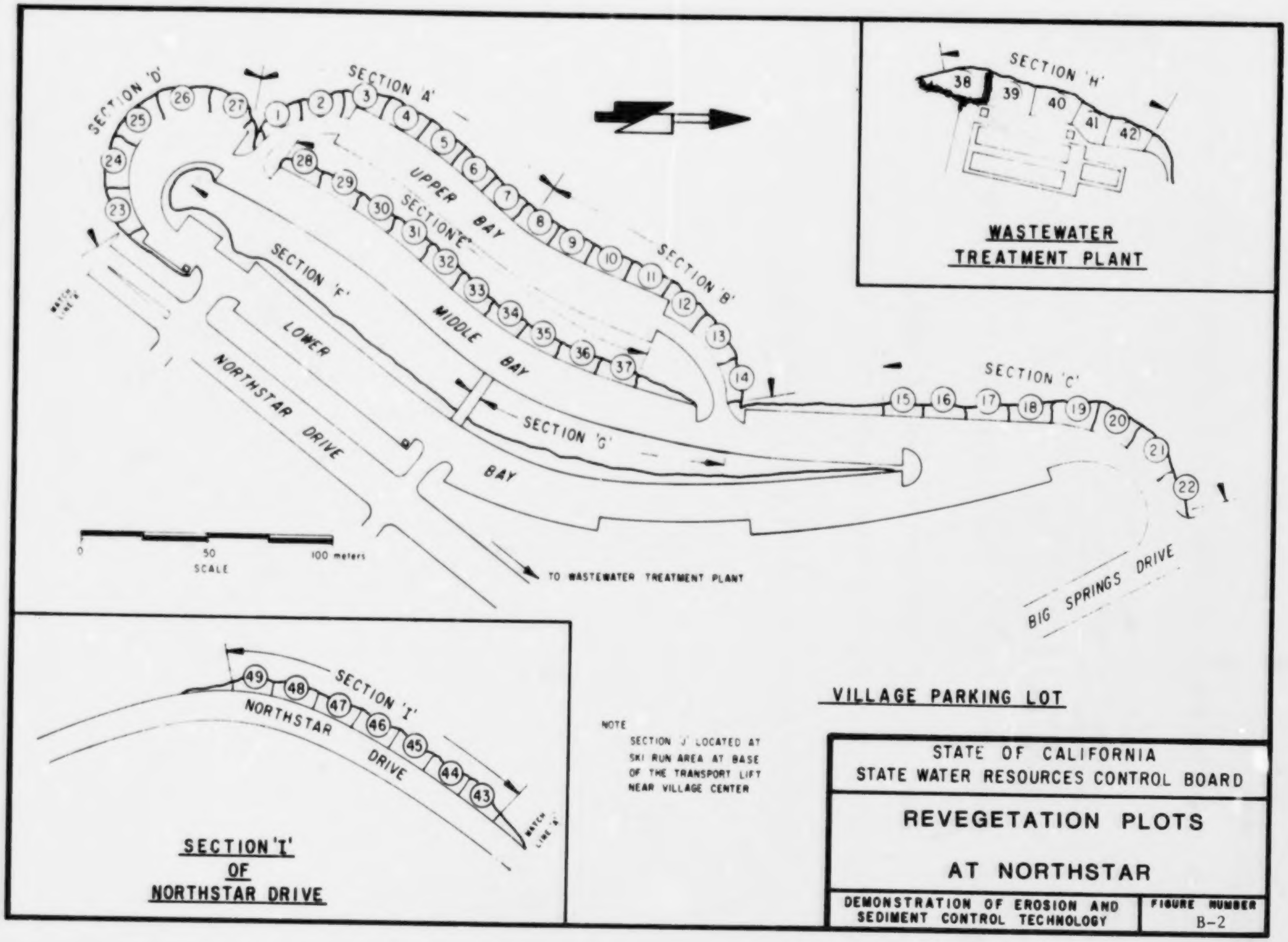
	%
Tegmar intermediate wheatgrass	30
Western wheatgrass	20
Manchar smooth brome	20
Sherman big bluegrass	20
Ranger alfalfa	10

HERB 12: Northeast facing fill slope adjacent to Big Springs Drive. Spring 1974.

Same herbaceous seed mixture as used in HERB 10.

HERB 13: Northeast facing fill slope adjacent to Big Springs Drive. Spring 1974.

Same herbaceous seed mixture as used in HERB 11.


SECTION 'A'
SECTION 'B'
SECTION 'C'
SECTION 'D'
SECTION 'E'
SECTION 'F'
SECTION 'G'
UPPER BAY
MIDDLE BAY
LOWER BAY
NORTHSTAR DRIVE
BIG SPRINGS DRIVE
VILLAGE PARKING LOT
TO WASTEWATER TREATMENT PLANT
0
50
100 meters
SCALE
MATCH LINE 'A'
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
SECTION 'H'
38
39
40
41
42
WASTEWATER TREATMENT PLANT
SECTION 'I'
NORTHSTAR DRIVE
43
44
45
46
47
48
49
MATCH LINE 'A'
SECTION 'I' OF NORTHSTAR DRIVE

NOTE
SECTION 'J' LOCATED AT
SKI RUN AREA AT BASE
OF THE TRANSPORT LIFT
NEAR VILLAGE CENTER

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

REVEGETATION PLOTS
AT NORTHSTAR

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER
B-2

TABLE B- 3 NORTHSTAR PLOT DESCRIPTIONS

A. PLOT DESCRIPTIONS								B. MECHANICAL STABILIZATION			C. PLANTS		D. SEEDING							E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. Bef./Aft.	5 O.H. Bef./Aft. (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. ($\frac{m^3}{\%}$)	11 Watt-ling ($\frac{rows}{m}$)	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre (Type) Kg/H	18 Straw Kg/H	19 Straw Tack (Type) Kg/H	20 Other Treat-ment	21 Type	22 Rate kg/ha •
SECTION A - FALL, 1975																					
1.	15.2 3.7	CUT 56	$\frac{32}{32}$	-	JTE	NE	50	ROCK .7M	-	$\frac{2.0}{30}$	100	STKS	-	-	-	-	-	-	-	-	-
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	I-2 3000	-	-	-	16-20	280
2	15.2 7.6	CUT 116	$\frac{32}{32}$	-	JTE	NE	50	ROCK .7M	-	$\frac{2.0}{30}$	200	STKS	-	-	-	-	-	-	-	-	-
"	RESEEDED - SPRING, '76												E 73	D 73	-	I-1 3700	-	-		16.20 M-A	336 260
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	I-2 3000	-	-	-	16-20	280
3	15.2 9.2	CUT 139	$\frac{32}{32}$	$\frac{2}{0}$	JTE	E	50-	CURB	$\frac{2}{100}$	$\frac{3.0}{45}$	80	SHRB (SC)	D 48	D 5.4	-	I-1 3250	-	PVA 11200	-	MA	400
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	I-2 3000	-	-	-	16-20	280
4	15.2 9.2	CUT 139	$\frac{32}{32}$	$\frac{5}{0}$	JTE	SE	50	CURB -	$\frac{5}{100}$	$\frac{3.5}{53}$	100	SHRB (SC)	D 47	D 4.7	-	-	RICE 4500	TTII 50	-	16-20 MA	336 280
5	15.2 8.6	CUT 130	$\frac{29}{29}$	$\frac{7}{0}$	JTE	SE	50	CURB -	$\frac{5}{70}$	$\frac{3.0}{45}$	250	STKS	-	-	-	-	-	-	-	-	-
"	RESEEDED - SPRING, '76												E 67	D 6.7	-	I-1 3360	-	-	-	16-20 M-A	336 260

TABLE B- 3 (Continued)

A. PLOT DESCRIPTIONS								B. MECHANICAL STABILIZATION			C. PLANTS		D. SEEDING							E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. Bef. Aft.	5 O.H. Bef. Aft. (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. $(\frac{m^3}{\%})$	11 Watt-ling $(\frac{\text{rows}}{m})$	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre (Type) Kg/H	18 Straw Kg/H	19 Straw Tack (Type) Kg/H	20 Other Treat-ment	21 Type	22 Rate kg/ha
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	I-2 3000	-	-	-	16-20	280
6	15.2 7.6	CUT 116	$\frac{29}{29}$	$\frac{2}{0}$	JTE	SE	50	CURB	$\frac{2}{100}$	3.0 45	-	-	D 47	D 47	-	I-2 3800	-	-	-	16-20 M-A	336 280
7	15.2 6.7	CUT 102	$\frac{29}{29}$	-	JTE	SE	50	CURB	-	$\frac{3.0}{45}$	-	-	-	-	-	-	-	-	-	-	-
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	I-2 3000	-	-	-	16-20	280
8	15.2 6.1	CUT 93	$\frac{29}{29}$	-	JTE	SE	50	CURB	-	$\frac{2.0}{30}$	-	-	D 48	D 5.4	-	I-1 3250	-	-	-	16-20	400
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	I-2 3000	-	-	-	16-20	280
SECTION B, FALL, 1975																					
9	15.2 5.2	CUT 79	$\frac{28}{28}$		JTE	SE	%)	CURB	-	-	-	-	-	-	-	-	-	-	-	-	-
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	I-2 3000	-	-	-	16-20	280
10	15.2 4.9	CUT 74	$\frac{28}{28}$	-	JTE	SE	50	CURB	-	-	-	-	D 260	D 22	-	I-1 4930	-	PVA 11200	-	M-A 16-20	1625 2634
11	15.2 6.1	CUT 93	$\frac{28}{28}$	-	JTE	SE	50	CURB	-	$\frac{2.0}{30}$	-	-	-	-	-	-	-	-	-	-	-
12	15.2 6.1	CUT 93	$\frac{28}{28}$	$\frac{2}{0}$	JTE	SE	-	ROCK 7M	$\frac{2}{100}$	$\frac{2.0}{30}$	-	-	D 47	D 4.7	-	I-2 3800	-	-	-	M-A 16-20	280 336

TABLE B- 3 (Continued)

A.	PLOT DESCRIPTIONS							B. MECHANICAL STABILIZATION			C. PLANTS		D.	SEEDING						E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. Bef. Aft.	5 O.H. Bef. Aft. (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. $(\frac{m^3}{\%})$	11 Watt-ling $(\frac{rows}{m})$	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre (Type) Kg/H	18 Straw Kg/H	19 Straw Tack (Type) Kg/H	20 Other Treat-ment	21 Type	22 Rate kg/ha
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	I-2 3000	-	-	-	16-20	280
13	15.2 4.3	CUT 65	$\frac{29}{29}$	-	JTE	SE	10	CURB	-	$\frac{1.5}{20}$	-	-	D 47	D 4.7	-	-	RICE 4500	$\frac{TTII}{50}$	-	M-A 16-20	280 336
14	15.2 4.9	CUT 75	$\frac{29}{29}$	-	JTE	SE	10	CURB	-	$\frac{2.0}{30}$	-	-	D 260	D 22	-	I-1 4930	-	-	-	M-A 16-20	1625 2634
SECTION C - FALL, 1975																					
15	15.2 4.6	CUT 70	$\frac{25}{25}$	-	JTE	E	25	CURB	-	$\frac{.5}{8}$	150	SHRB (SC)	-	-	-	-	-	-	-	-	-
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	I-2 3000	-	-	-	16-20	280
16	15.2 9.2	CUT 139	$\frac{32}{32}$	-	JTE	E	80	CURB	-	$\frac{2.5}{38}$	-	-	D 47	D 4.7	-	I-1 3360	-	-	-	M-A 16-20	280 336
17	15.2 6.1	CUT 93	$\frac{34}{34}$	-	JTE	E	80	CURB	-	$\frac{3.0}{30}$	-	-	-	-	-	-	-	-	-	-	-
18	15.2 10.7	CUT 163	$\frac{33}{33}$	$\frac{5}{1}$	JTE H-P	E	80	CURB	$\frac{4}{80}$	$\frac{3.0}{45}$	-	-	D 47	D 4.7	-	I-1 3360	-	PVA 11200	-	M-A 16-20	280 336
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	I-2 3000	-	-	-	16-20	280
19	15.2 13.4	CUT 204	$\frac{32}{32}$	$\frac{5}{1}$	JTE H-P	E	80	CURB	$\frac{4}{80}$	$\frac{6.0}{60}$	-	-	D 47	D 4.7	-	-	RICE 4500	$\frac{TTII}{50}$	-	M-A 16-20	280 336
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	I-2 3000	-	-	-	16-20	280

TABLE B- 3 (Continued)

A.	PLOT DESCRIPTIONS							B. MECHANICAL STABILIZATION			C. PLANTS		D.	SEEDING						E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. $\frac{Bef.}{Aft.}$	5 O.H. $\frac{Bef.}{Aft.}$ (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. $(\frac{m^3}{\%})$	11 Watt-ling $(\frac{rows}{m})$	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre $\frac{(Type)}{Kg/H}$	18 Straw Kg/H	19 Straw Tack $\frac{(Type)}{Kg/H}$	20 Other Treat-ment	21 Type	22 Rate kg/ha
20	10.3 10.7	CUT 110	$\frac{32}{32}$	$\frac{3}{1}$	JTE H-P	E	70	CURB	$\frac{2}{67}$	-	-	-	-	-	-	-	-	-	-	-	-
21	15.2 10.4	CUT 158	$\frac{31}{31}$	$\frac{6}{1}$	JTE H-P	SE	60	ROCK .7M	$\frac{5}{83}$	$\frac{3.0}{45}$	-	-	-	-	-	-	-	-	-	-	-
"	RESEEDED - SPRING, '76												E 60	D 6.0	- -	I-1 3000	-	-	-	16-20	300
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	I-2 3000	-	-	-	16-20	280
22	15.2 6.1	CUT 93	$\frac{29}{29}$	$\frac{2}{0}$	JTE	SE	50	ROCK .7M	$\frac{2}{100}$	$\frac{2.0}{30}$	-	-	D 47	D 4.7	-	I-2 3360	-	-	-	M-A 16-20	280 336
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	I-2 3000	-	-	-	16-20	280
SECTION D - FALL, 1975																					
23	15.2 12.2	CUT 186	$\frac{32}{32}$	-	JTE	N	-	CURB	-	-	-	-	D 58	D 4.7	-	I-2 3475	-	-	-	M-A 16-20	280 386
24	15.2 12.2	CUT 186	$\frac{32}{32}$	-	JTE	N	-	CURB	-	-	-	-	D 58	D 4.7	-	-	RICE 4500	$\frac{TTII}{50}$	-	M-A 16-20	280 336
25	15.2 11.0	CUT 167	$\frac{32}{32}$	-	JTE	NE	-	CURB (SC)	-	-	200	SHRB	-	-	-	-	-	-	-	-	-
"	RESEEDED - SPRING, '76												E 45	D 4.5	- -	I-1 3360	-	-	-	16-20 M-A	336 260

TABLE B- 3 (Continued)

A.	PLOT DESCRIPTIONS							B. MECHANICAL STABILIZATION			C. PLANTS		D.	SEEDING						E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. Bef./Aft.	5 O.H. Bef./Aft. (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. ($\frac{m^3}{\%}$)	11 Watt-ling ($\frac{rows}{m}$)	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre (Type) Kg/H	18 Straw Kg/H	19 Straw Tack (Type) Kg/H	20 Other Treat-ment	21 Type	22 Rate kg/ha
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	-	WHEAT 3250	SSEC 100	-	16-20	280
26	15.2 9.2	CUT 139	32/32	- -	JTE	NE	10	CURB	-	-	-	-	D 47	D 4.7	-	I-1 3360	-	-	-	M-A 16-20	280 336
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	-	WHEAT 3250	SSEC 100	-	16-20	280
27	15.2 9.2	CUT 139	32/32	-	JTE	E	20	CURB	-	-	-	-	D 47	D 4.7	-	I-1 3360	-	PVA 11200	-	M-A 16-20	280 336
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	-	WHEAT 3250	SSEC 100	-	16-20	280
SECTION E - FALL 1975																					
28	15.2 3.1	CUT 46	32/32	-	JTE	SE	-	CURB	-	-	-	-	D 47	D 4.7	-	I-2 3475	-	PVA 11200	-	M-A 16-20	280 336
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	-	WHEAT 3250	SSEC 100	-	16-20	280
29	3.7	CUT 56	32/32	-	JTE	SE	-	CURB	-	-	-	-	D 47	D 4.7	-	-	RICE 4500	TTII 50	-	M-A 16-20	280 336
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	-	WHEAT 3250	SSEC 100	-	16-20	280
30	15.2 4.6	CUT 70	32/32	-	JTE	SE	-	CURB	-	-	-	-	-	-	-	-	-	-	-	-	-
"	RESEEDED - SPRING, '76												E 100	D 10.0	-	I-1 3360	-	-	-	16-20	650

TABLE B- 3 (Continued)

A.	PLOT DESCRIPTIONS							B. MECHANICAL STABILIZATION			C. PLANTS		D.	SEEDING						E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. Bef./Aft.	5 O.H. Bef./Aft. (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. ($\frac{m^3}{\%}$)	11 Watt-ling ($\frac{rows}{m}$)	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre (Type)/Kg/H	18 Straw Kg/H	19 Straw Tack (Type)/Kg/H	20 Other Treat-ment	21 Type	22 Rate kg/ha
"	RESEEDED - SPRING, '76												E 100	E 5	D 7	-	WHEAT 3250	SSEC 100	-	16-20	280
31	15.2 6.1	CUT 93	32/32	-	JTE	SE	-	CURB	-	-	-	-	D 45	D 45	-	I-1 3360	-	-	-	M-A 16-20	336 364
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	-	WHEAT 4500	TTII 100	-	16-20	280
32	15.2 6.1	CUT 93	32/32	-	JTE	SE	-	CURB	-	-	-	-	D 45	D 4.5	-	I-1 3025	- -	PVA 11200	-	M-A 16-20	290 325
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	-	WHEAT 4500	TTII 100	-	16-20	280
33	15.2 6.1	CUT 93	32/32	-	JTE	SE	-	CURB	-	-	-	-	D 57	D 4.7	-	I-2 3475	-	-	-	M-A 16-20	280 336
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	-	WHEAT 4500	TTII 100	-	16-20	280
34	15.2 5.5	CUT 84	32/32	-	JTE	SE	-	CURB	-	-	-	-	D 57	D 4.7	-	-	RICE 4500	TTII 50	-	M-A 16-20	280 336
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	-	WHEAT 4500	WF 850	-	16-20	280
35	15.2 5.2	CUT 79	32/32	-	JTE	SE	-	CURB	-	-	-	-	-	-	-	-	-	-	-	-	-
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	-	WHEAT 4500	WF 850	-	16-20	280

TABLE B- 3 (Continued)

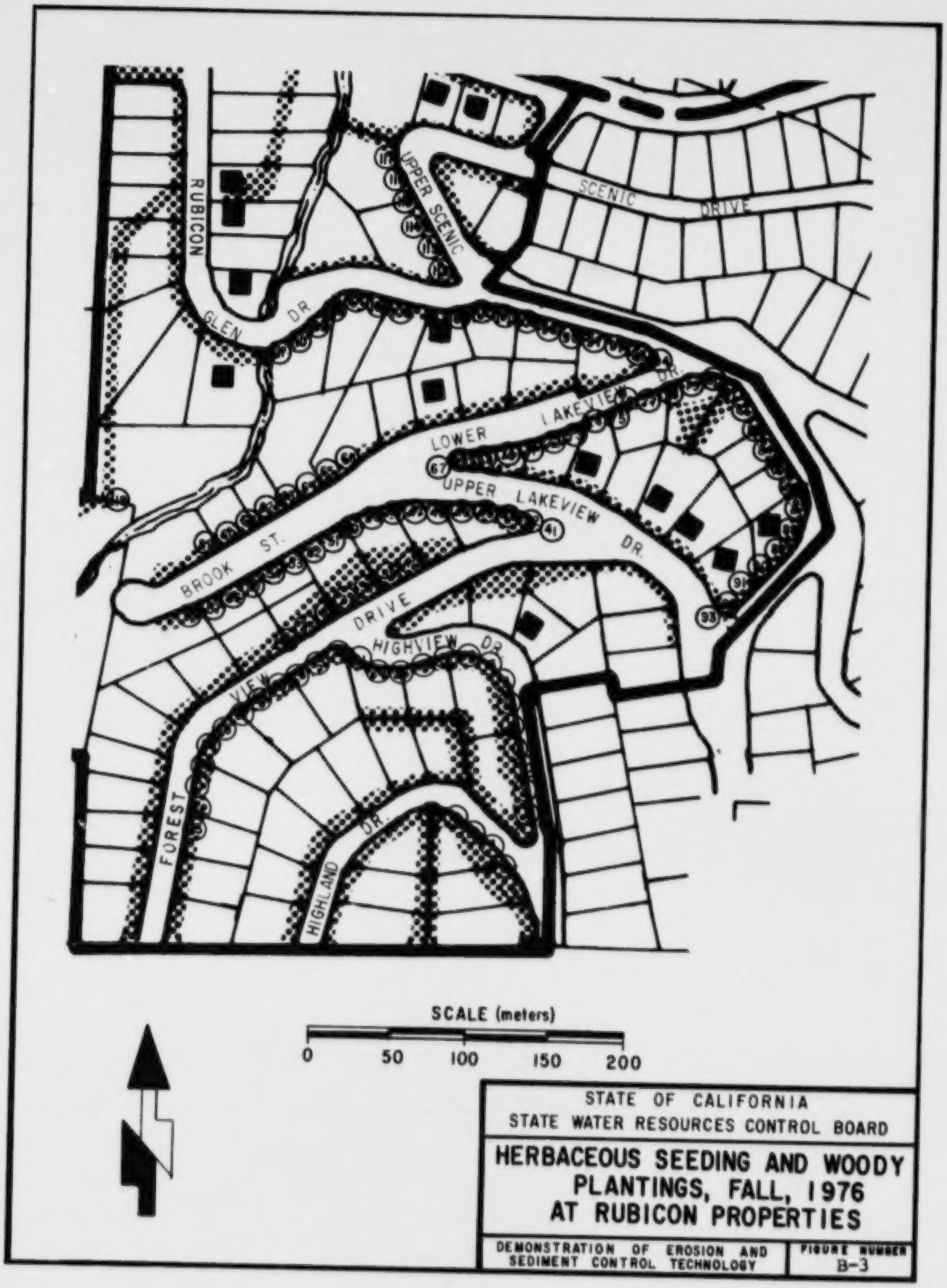
A.	PLOT DESCRIPTIONS							B. MECHANICAL STABILIZATION			C. PLANTS		D.	SEEDING						E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. Bef. Aft.	5 O.H. Bef. Aft. (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. $(\frac{m^3}{\%})$	11 Watt-ling $(\frac{rows}{m})$	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre $\frac{(Type)}{Kg/H}$	18 Straw Kg/H	19 Straw Tack $\frac{(Type)}{Kg/H}$	20 Other Treat-ment	21 Type	22 Rate kg/ha
36	15.2 3.7	CUT 56	32 32	-	JTE	SE	-	CURB	-	-	-	-	D 45	D 4.5	-	-	-	-	-	M-A 16-20	290 325
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	-	WHEAT 4500	WF 850	-	16-20	280
37	15.2 3.1	CUT 46	32 32	-	JTE	SE	-	CURB	-	-	-	-	D 45	D 4.5	-	I-1 3600	-	PVA 11200	-	M-A 16-20	290 325
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	-	WHEAT 4500	WF 850	-	16-20	280
SECTION F - FALL, 1975																					
F	150 3.3	CUT 500	34 34	-	JTE	SE	-	CURB	-	-	-	-	D 45	D 4.5	-	I-1 3475	-	-	-	M-A 16-20	285 350
"	RESEEDED - SPRING, '77												E 100	E 5	D 7	-	WHEAT 4500	IITT 100	-	16-20	280
SECTION G - FALL 1975																					
G	100 5.0	CUT 500	34 34	-	JTE	SE	-	CURB	-	-	-	-	D 45	D 4.5	-	I-2 3025	-	-	-	M-A 16-20	295 350
"	RESEEDED - SPRING, '77 SOUTH 1/2												E 100	E 5	D 7	-	WHEAT 3250	SSEC 100	-	16-20	280
	" " " NORTH 1/2												B 100	E 5	D 7	-	WHEAT 4500	850 WF	-	16-20	280
SECTION H - FALL 1975																					
38	15.2 4.6	CUT 70	26 26	-	JTE	E	50	CURB	-	2.0 30	-	-	D 47	D 4.7	-	I-1 3475	-	-	-	M-A 16-20	285 350

TABLE B- 3 (Continued)

A.	PLOT DESCRIPTIONS							B. MECHANICAL STABILIZATION			C. PLANTS		D.	SEEDING						E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. $\frac{\text{Bef.}}{\text{Aft.}}$	5 O.M. $\frac{\text{Bef.}}{\text{Aft.}}$ (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.M. ($\frac{m^3}{\%}$)	11 Wattling $\frac{\text{(rows)}}{m}$	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre (Type) Kg/H	18 Straw Kg/H	19 Straw Tack (Type) Kg/H	20 Other Treatment	21 Type	22 Rate kg/ha
39	15.2 8.6	CUT 130	$\frac{28}{28}$	-	JTE	E	70	CURB	-	$\frac{3.0}{45}$	-	-	D 47	D 4.7	-	I-1 3475	-	PVA 11200	-	M-A 16-20	285 350
40	15.2 9.2	CUT 139	$\frac{28}{28}$	-	JTE	E	50	CURB	-	$\frac{3.5}{50}$	-	-	D 47	D 4.7	-	-	RICE 4500	TTII 50	-	U-F -	336 -
41	15.2 8.6	CUT 130	$\frac{26}{26}$	-	JTE	E	25	CURB	-	$\frac{2.5}{35}$	-	-	D 47	D 4.7	-	I-2 3475	-	-	-	M-A 16-20	285 336
42	15.2 8.6	CUT 130	$\frac{22}{22}$	-	JTE	E	15	CURB	-	$\frac{2.0}{30}$	-	-	D 47	D 4.7	-	I-2 3475	-	-	-	M-A 16-20	285 336
SECTION I - SPRING 1976																					
43	15.2 4.6	CUT 70	$\frac{26}{26}$	-	JTE	E	-	CURB	-	-	-	-	D 45	D 6.7	- -	I-1 3363	-	-	-	16-20 -	336 -
44	15.2 6.1	CUT 73	$\frac{26}{26}$	-	JTE	E	-	CURB	-	-	-	-	D 50	D 5.0	-	I-1 2240	-	-	-	16-20	365
45	15.2 6.1	CUT 93	$\frac{26}{26}$	-	JTE	0	-	CURB	-	-	-	-	D 73	D 7.3	-	I-1 2240	-	-	-	16-20 -	490 -
46	15.2 6.1	CUT 93	$\frac{26}{26}$	-	JTE	E	-	CURB	-	-	-	-	D 100	D 100	-	II-1 2240	-	-	-	16-20 -	490 -
47	15.2 6.1	CUT 93	$\frac{26}{26}$	-	JTE	0	-	CURB	-	-	-	-	D 100	D 10.0	- -	I-1 3700	-	-	-	16-20 -	490 -
48	15.2 6.1	CUT 93	$\frac{26}{26}$	-	JTE	E	-	CURB	-	-	-	-	D 50	D 5.0	- -	J-1 2240	-	-	-	16-20 -	245 -
49	15.2 3.7	CUT 56	$\frac{26}{26}$		JTE	E	-	CURB	-	-	-	-	D 100	D 10.0	- -	I-1 4035	-	-	-	16-20 -	280 -

TABLE B- 3 (Continued)

A.		PLOT DESCRIPTIONS						B. MECHANICAL STABILIZATION			C. PLANTS		D. SEEDING							E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. $\frac{\text{Bef.}}{\text{Aft.}}$	5 O.H. $\frac{\text{Bef.}}{\text{Aft.}}$ (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. ($\frac{m^3}{\%}$)	11 Watt-ling ($\frac{\text{rows}}{m}$)	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre (Type) Kg/H	18 Straw Kg/H	19 Straw Tack (Type) Kg/H	20 Other Treat-ment	21 Type	22 Rate kg/ha
SECTION J - FALL 1975																					
J	N/A	FILL 6070	0-25 0-25	N/A	JTE	N/A	-	N/A	N/A	-	-	-	(Drilled) 34	4.7	34	-	RICE 4500	-	-	16-20 -	280 -


RUBICON
GLEN DR
UPPER SCENIC
SCENIC DRIVE
LOWER LAKEVIEW DR.
67
UPPER LAKEVIEW DR.
41
BROOK ST.
DRIVE
HIGHVIEW DR.
VIEW
FOREST
HIGHLAND DR.
91
93
SCALE (meters)
0
50
100
150
200

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

HERBACEOUS SEEDING AND WOODY PLANTINGS, FALL, 1976 AT RUBICON PROPERTIES

DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY

FIGURE NUMBER B-3

TABLE B-4 RUBICON PROPERTIES PLOT DESCRIPTIONS - SUMMER AND FALL 1976

A. PLOT DESCRIPTIONS								B. MECHANICAL STABILIZATION			C. PLANTS		D. SEEDING							E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. $\frac{Bef.}{Aft.}$	5 O.H. $\frac{Bef.}{Aft.}$ (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. $(\frac{m^3}{\%})$	11 Watt-ling $(\frac{rows}{m})$	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre (Type) Kg/H	18 Straw Kg/H	19 Straw Tack (Type) Kg/H	20 Other Treat-ment	21 Type	22 Rate kg/ha
1	15.2 9.1	CUT 139	$\frac{42}{35}$	-	MsG	NE	-	ROCK 1.2	-	-	-	-	A 41	A 12	A 2.2	I-1 2800	-	-	-	16-20	280
2	15.2 13.1	CUT 200	$\frac{45}{41}$	$\frac{11}{5}$	DG MsG	"	-	"	$\frac{6}{54}$	$\frac{2}{30}$	-	-	C 86	C 21	C 0.2	-	DAVIS 4500	-	JUTE	"	"
4	15.2 14.3	CUT 218	$\frac{45}{42}$	$\frac{11}{5}$	"	"	-	"	$\frac{6}{54}$	$\frac{4}{60}$	-	-	"	"	"	-	"	-	"	"	"
5	15.2 15.2	CUT 232	$\frac{45}{45}$	$\frac{11}{5}$	MsG DG	" "	- -	" "	$\frac{6}{54}$	$\frac{2}{30}$	-	-	A 83	A 25	A 4.5	-	"	-	-	"	"
6	15.2 14.3	CUT 218	$\frac{48}{45}$	$\frac{11}{8}$	DG	"	20	"	$\frac{3}{27}$	$\frac{2}{30}$	-	-	"	"	"	I-1 5600	-	-	-	"	"
7	15.2 6.7	CUT 102	$\frac{40}{35}$	-	MsG	E	-	"	-	$\frac{2}{30}$	-	-	A 83	A 25	A 4.5	II-1 5600	-	-	-	"	"
8	15.2 13.4	CUT 204	$\frac{40}{35}$	-	MsG DG	"	-	"	- -	$\frac{1.5}{23}$	-	-	"	"	"	"	-	-	-	"	"
9	15.2 8.2	CUT 125	$\frac{48}{43}$	$\frac{5}{2}$	DG MsG	"	-	"	$\frac{3}{60}$	$\frac{1}{15}$	-	-	A 41	A 12	A 2.2	-	-	-	-	"	"
10	15.2 9.1	CUT 139	$\frac{45}{40}$	$\frac{6}{2}$	"	"	-	"	$\frac{4}{66}$	$\frac{1.5}{23}$	-	-	C 86	C 21	C 0.2	-	DAVIS 4500	-	JUTE	"	"

TABLE B-4 (CONTINUED)

A.		PLOT DESCRIPTIONS						B. MECHANICAL STABILIZATION			C. PLANTS		D.			SEEDING				E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. $\frac{\text{Bef.}}{\text{Aft.}}$	5 O.H. $\frac{\text{Bef.}}{\text{Aft.}}$ (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. $(\frac{m^3}{\%})$	11 Watt-ling $(\frac{\text{rows}}{m})$	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre $\frac{\text{(Type)}}{\text{Kg/H}}$	18 Straw Kg/H	19 Straw Tack $\frac{\text{(Type)}}{\text{Kg/H}}$	20 Other Treat-ment	21 Type	22 Rate kg/ha
11	15.2 10.0	CUT 153	$\frac{42}{38}$	$\frac{6}{2}$	"	"	-	"	$\frac{4}{66}$	$\frac{2.5}{38}$	-	-	"	"	"	-	-	-	MG 1412	16-20	280
12	15.2 12.2	CUT 185	$\frac{45}{40}$	$\frac{6}{2}$	"	"	-	"	$\frac{4}{66}$	$\frac{3}{45}$	-	-	A 41	A 12	A 2.2	-	PMC 4500	$\frac{\text{SSEC}}{150}$	-	"	"
13	15.2 16.8	CUT 256	$\frac{45}{40}$	$\frac{6}{2}$	MsG DG	"	-	"	$\frac{4}{66}$	$\frac{3}{45}$	-	-	"	"	"	-	BOTH 4500	$\frac{\text{TTII}}{100}$	- -	"	"
14	15.2 19.8	CUT 302	$\frac{45}{41}$	$\frac{6}{2}$	" "	" "	-	"	$\frac{4}{66}$	$\frac{4}{60}$	20 55	GRS SHRB	A 83	A 25	A 4.5	III-1 4100	-	-	-	"	"
15	15.2 18.3	CUT 279	$\frac{45}{42}$	$\frac{3}{1}$	"	NE	-	"	$\frac{4}{66}$	$\frac{2}{60}$	60 30	GRS SHRB	"	"	"	II-1 2800	-	-	-	"	"
16	15.2 18.3	CUT 279	$\frac{45}{42}$	-	"	"	-	"	- -	$\frac{3}{35}$	30 20	GRS SHRB	"	"	"	I-1 2800	-	-	-	"	"
17	15.2 18.3	CUT 279	$\frac{42}{35}$	$\frac{4.5}{2.0}$	"	N	-	"	$\frac{2.5}{55}$	$\frac{10}{152}$	550	BOTH	"	"	"	-	BOTH 4500	$\frac{\text{TTII}}{100}$	-	"	"
18	15.2 16.8	CUT 256	$\frac{40}{38}$	$\frac{4.5}{2.0}$	"	"	-	"	$\frac{2.5}{55}$	$\frac{9}{137}$	500	BOTH	A 41	A 12	A 2.2	-	"	$\frac{\text{TTSC}}{50}$	-	"	"
19	15.2 14.6	CUT 223	$\frac{40}{38}$	$\frac{6}{3}$	MsG DG	N	-	ROCK 1.2	$\frac{3}{50}$	$\frac{9}{137}$	500	BOTH	A 83	A 25	A 4.5	- -	PMC 4500	$\frac{\text{SSEC}}{150}$	-	"	"
20	15.2 19.8	CUT 302	$\frac{40}{40}$	$\frac{2}{1}$	"	"	-	"	$\frac{1}{50}$	$\frac{12}{182}$	650	BOTH	"	"	"	II-3 2800	-	-	-	"	"

TABLE B-4 (CONTINUED)

A.	PLOT DESCRIPTIONS							B. MECHANICAL STABILIZATION			C. PLANTS		D.	SEEDING						E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. $\frac{\text{Bef.}}{\text{Aft.}}$	5 O.H. $\frac{\text{Bef.}}{\text{Aft.}}$ (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. ($\frac{m^3}{\%}$)	11 Watt-ling $\frac{\text{(rows)}}{\text{m}}$	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre $\frac{\text{(Type)}}{\text{Kg/H}}$	18 Straw Kg/H	19 Straw Tack $\frac{\text{(Type)}}{\text{Kg/H}}$	20 Other Treat-ment	21 Type	22 Rate kg/ha
21	15.2 22.9	CUT 349	$\frac{42}{40}$	-	MsG	"	-	"	- -	$\frac{12}{182}$	650	BOTH	A 41	A 12	A 2.2	III-1 2800	-	-	-	16-20	280
22	15.2 19.8	CUT 302	$\frac{45}{40}$	-	"	"	-	"	- -	$\frac{10}{152}$	550	BOTH	A 83	A 25	A 4.5	III-1 2800	-	-	-	"	"
23	15.2 13.7	CUT 209	$\frac{45}{40}$	-	"	"	-	"	- -	$\frac{6}{91}$	350	BOTH	A 41	A 12	A 2.2	II-1 2800	-	-	-	"	"
24	15.2 9.1	CUT 139	$\frac{45}{38}$	$\frac{20}{4}$	"	NW	-	CURB 0.3	$\frac{16}{80}$	$\frac{6}{91}$	-	-	A 83	A 25	A 4.5	II-1 5600	-	-	-	"	"
25	15.2 9.1	CUT 139	$\frac{48}{34}$	$\frac{10}{4}$	"	"	-	"	$\frac{6}{60}$	-	-	-	C 43	C 11	C 0.1	-	DAVIS 4500	$\frac{\text{DOWX}}{1510}$	-	"	"
26	15.2 9.1	CUT 139	$\frac{48}{35}$	$\frac{10}{4}$	"	"	-	"	$\frac{6}{60}$	-	-	-	"	"	"	-	DAVIS 4500	$\frac{\text{DOW2}}{755}$	-	"	"
27	15.2 9.1	CUT 139	$\frac{45}{36}$	$\frac{10}{4}$	"	"	-	"	$\frac{6}{60}$	-	-	-	"	"	"	-	DAVIS 4500	$\frac{\text{W.F.}}{1120}$	-	"	"
28	6.1 9.1	CUT 56	$\frac{45}{35}$	$\frac{10}{4}$	"	"	-	"	$\frac{6}{60}$	-	200 (H.O.)	SHRB	-	-	-	-	-	-	HG 1210	"	"
29	15.2 6.1	CUT 116	$\frac{40}{33}$	$\frac{10}{4}$	"	"	-	"	$\frac{6}{60}$	-	-	-	A 41	A 12	A 2.2	-	PMC 4500	$\frac{\text{TTSC}}{50}$	-	"	"

TABLE B-4 (CONTINUED)

A. PLOT DESCRIPTIONS								B. MECHANICAL STABILIZATION			C. PLANTS		D. SEEDING							E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m²)	4 Deg. Bef./Aft.	5 O.H. Bef./Aft. (m³)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. (m³/%)	11 Wattling (rows/m)	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre (Type)/Kg/H	18 Straw Kg/H	19 Straw Tack (Type)/Kg/H	20 Other Treatment	21 Type	22 Rate kg/ha
30	15.2 7.0	CUT 107	35/35	10/6	"	"	-	"	4/40	-	-	-	"	"	"	-	DAVIS 4500	SSEC/150	-	16-20	280
31	6.1 7.0	CUT 43	35/35	-	"	"	-	"	-	-	-	-	"	"	"	-	"	"	-	"	"
32	15.2 6.1	CUT 93	40/34	-	"	"	-	"	-	-	-	-	"	"	"	I-3 2800	-	-	-	"	"
33	7.6 6.1	CUT 46	40/34	-	"	"	-	"	-	-	-	-	"	"	"	"	-	-	-	"	"
34	15.2 15.2	FILL 232	35/35	-	"	"	-	-	-	-	150 (SDF)	TRS	"	"	"	"	-	-	-	"	"
35	15.2 33.5	FILL 511	35/35	-	"	"	-	-	-	-	340 (SDF)	TRS	A 83	A 25	A 4.5	I-3 5600	-	-	-	"	"
36	15.2 32.0	FILL 488	36/36	-	"	"	-	-	-	-	320 (SDF)	TRS	"	"	"	"	-	-	-	"	"
37	15.2 33.5	FILL 511	37/37	-	MsG	NW	-	-	-	-	340 (SDF)	TRS	A 83	A 25	A 4.5	-	DAVIS 4500	SSEC/150	(WF)/(224)	"	"
38	15.2 30.4	FILL 465	36/36	-	"	"	-	-	-	-	-	-	"	"	"	-	"	TTSC/50	(WF)/(77)	"	"
39	15.2 29.0	FILL 441	36/36	-	"	"	-	-	-	-	-	-	"	"	"	-	BOTH 4500	TTII/100	(WF)/(336)	"	"

TABLE B-4 (CONTINUED)

A. PLOT DESCRIPTIONS								B. MECHANICAL STABILIZATION			C. PLANTS		D. SEEDING							E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. $\frac{\text{Bef.}}{\text{Aft.}}$	5 O.H. $\frac{\text{Bef.}}{\text{Aft.}}$ (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. ($\frac{m^3}{\%}$)	11 Watt-ling $\frac{\text{(rows)}}{m}$	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre $\frac{\text{(Type)}}{\text{Kg/H}}$	18 Straw Kg/H	19 Straw Tack $\frac{\text{(Type)}}{\text{Kg/H}}$	20 Other Treat-ment	21 Type	22 Rate kg/ha
40.	15.2 27.4	FILL 418	$\frac{36}{36}$	-	"	"	-	-	-	-	-	-	C 86	C 21	C 0.2	-	DAVIS 4500	$\frac{\text{W.F.}}{1120}$	-	16-20	280
41	15.2 7.6	CUT 116	$\frac{34}{34}$	$\frac{7}{4}$	"	N	-	GAB 0.9	$\frac{3}{42}$	-	-	-	A 41	A 12	A 2.2	I-1 2800	-	-	-	"	"
42	15.2 6.7	CUT 102	$\frac{40}{37}$	$\frac{6}{4}$	"	"	-	"	$\frac{2}{33}$	-	-	-	C 86	C 21	C 0.2	- -	-	-	HG 1410	"	"
43	15.2 6.7	CUT 102	$\frac{48}{40}$	$\frac{12}{4}$	"	"	-	"	$\frac{8}{66}$	-	-	-	A 83	A 25	A 4.5	I-1 2800	-	-	-	"	"
44	15.2 7.6	CUT 116	$\frac{50}{37}$	$\frac{12}{4}$	"	"	-	"	$\frac{8}{66}$	-	-	-	"	"	"	I-1 5600	-	-	-	"	"
45	15.2 6.1	CUT 102	$\frac{45}{36}$	$\frac{12}{4}$	"	"	-	"	$\frac{8}{66}$	-	-	-	A 41	A 12	A 2.2	-	DAVIS 4500	$\frac{\text{TTSC}}{50}$	$\frac{\text{(WF)}}{(77)}$	"	"
46	15.2 6.1	CUT 93	$\frac{40}{36}$	$\frac{12}{4}$	"	"	-	"	$\frac{8}{66}$	-	-	-	C 86	C 21	C 0.2	-	"	- -	JUTE	"	"
47	15.2 6.1	CUT 93	$\frac{40}{36}$	$\frac{12}{4}$	"	"	-	GAB 1.8	$\frac{8}{66}$	-	50	GRS	"	"	"	-	"	$\frac{\text{DOW1}}{755}$	-	"	"
48	15.2 6.1	CUT 93	$\frac{45}{38}$	$\frac{12}{2}$	"	"	-	"	$\frac{10}{83}$	-	50	GRS	"	"	"	-	"	$\frac{\text{DOW2}}{755}$	$\frac{\text{(WF)}}{(230)}$	"	"
49	15.2 6.1	CUT 93	$\frac{40}{35}$	$\frac{12}{2}$	"	"	-	"	$\frac{10}{83}$	-	50	GRS	"	"	"	-	"	$\frac{\text{DOW3}}{755}$	$\frac{\text{(WF)}}{(460)}$	"	"

TABLE B-4 (CONTINUED)

A.	PLOT DESCRIPTIONS							B. MECHANICAL STABILIZATION			C. PLANTS		D.	SEEDING						E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. $\frac{\text{Bef.}}{\text{Aft.}}$	5 O.H. $\frac{\text{Bef.}}{\text{Aft.}}$ (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. ($\frac{m^3}{\%}$)	11 Watt-ling ($\frac{\text{rows}}{m}$)	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre $\frac{\text{(Type)}}{\text{Kg/H}}$	18 Straw Kg/H	19 Straw Tack $\frac{\text{(Type)}}{\text{Kg/H}}$	20 Other Treat-ment	21 Type	22 Rate kg/ha
50	15.2 7.6	CUT 116	$\frac{55}{35}$	$\frac{12}{2}$	"	NW	-	"	$\frac{10}{83}$	-	-	-	A 41	A 12	A 2.2	-	"	$\frac{\text{SSEC}}{150}$	$\frac{\text{(WF)}}{(224)}$	16-20	280
51	15.2 7.6	CUT 116	$\frac{50}{32}$	$\frac{10}{4}$	"	"	-	"	$\frac{6}{60}$	-	-	-	A 83	A 25	A 4.5	-	BOTH 4500	$\frac{\text{TTSC}}{50}$	$\frac{\text{(WF)}}{(77)}$	"	"
52	15.2 7.6	CUT 116	$\frac{40}{34}$	$\frac{10}{4}$	"	"	-	GAB .9	$\frac{6}{60}$	-	-	-	A 41	A 12	A 2.2	-	DAVIS 4500	- -	CON- WED	"	"
53	15.2 10.7	CUT 163	$\frac{45}{40}$	$\frac{10}{5}$	"	"	-	"	$\frac{5}{50}$	-	-	-	"	"	"	III-3 2800	-	-	-	"	"
54	15.2 7.6	CUT 116	$\frac{50}{40}$	$\frac{7}{4}$	"	"	-	GAB 18	$\frac{3}{43}$	-	-	-	A 83	A 25	A 4.5	"	-	-	-	"	"
55	15.2 9.1	CUT 139	$\frac{40}{33}$	$\frac{6}{2}$	MsG	NW	-	GAB 6'	$\frac{4}{66}$	-	-	-	A 83	A 25	A 4.5	III-3 5600	-	-	-	"	"
56	15.2 7.6	CUT 116	$\frac{40}{31}$	$\frac{8}{3}$	"	"	-	GAB 3'	$\frac{5}{62}$	-	-	-	"	"	"	-	-	-	EXCEL	"	"
57	15.2 6.1	CUT 93	$\frac{40}{33}$	$\frac{8}{4}$	"	"	-	GAB 3'	$\frac{4}{50}$	-	-	-	"	"	"	-	-	-	"	"	"
58	15.2 7.6	CUT 116	$\frac{38}{34}$	$\frac{8}{4}$	"	"	-	GAB 3'	$\frac{4}{50}$	-	-	-	A 41	A 12	A 2.2	II-3 2800	-	-	-	"	"
59	15.2 6.1	FILL 93	$\frac{34}{34}$	-	"	"	-	-	-	-	-	-	"	"	"	III-1 2800	-	-	-	"	"

TABLE B-4 (CONTINUED)

A.		PLOT DESCRIPTIONS						B. MECHANICAL STABILIZATION			C. PLANTS		D.		SEEDING						E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. $\frac{\text{Bef.}}{\text{Aft.}}$	5 O.H. $\frac{\text{Bef.}}{\text{Aft.}}$ (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. ($\frac{m^3}{\%}$)	11 Watt-ling $\frac{(\text{rows})}{m}$	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre $\frac{(\text{Type})}{\text{Kg/H}}$	18 Straw Kg/H	19 Straw Tack $\frac{(\text{Type})}{\text{Kg/H}}$	20 Other Treat-ment		21 Type	22 Rate kg/ha
60	15.2 6.1	FILL 93	$\frac{36}{36}$	-	"	"	-	-	-	-	-	-	A 83	A 25	A 4.5	III-1 2800	-	-	-		16-20	280
61	15.2 6.1	FILL 93	$\frac{36}{36}$	-	"	"	-	-	-	-	-	-	"	"	"	III-1 5600	-	-	-		"	"
62	15.2 6.1	FILL 93	$\frac{37}{37}$	-	"	"	-	-	-	-	-	-	A 41	A 12	A 2.2	III-3 2800	-	-	-		"	"
63	15.2 9.1	FILL 139	$\frac{37}{37}$	-	"	"	-	-	-	-	-	-	A 83	A 25	A 4.5	III-3 2800	-	-	-		"	"
64	15.2 9.1	FILL 139	$\frac{37}{37}$	-	"	"	-	-	-	-	-	-	"	"	"	III-3 5600	-	-	-		"	"
65	21.3	FILL	$\frac{36}{36}$	-	"	"	-	-	-	-	-	-	-	-	-	-	-	-	-		"	"
66	15.2 10.7	FILL 163	$\frac{35}{35}$	-	"	"	-	-	-	-	-	-	A 41	A 12	A 2.2	-	BOTH 4500	$\frac{\text{TTSC}}{50}$	$\frac{(\text{WF})}{(77)}$		"	"
67	15.2 7.6	CUT 116	$\frac{33}{32}$	$\frac{1}{0}$	"	N	-	GAB 3'	$\frac{1}{100}$	-	-	-	A 83	A 25	A 4.5	-	DAVIS 4500	$\frac{\text{TTII}}{100}$	$\frac{(\text{WF})}{(336)}$		"	"
68	15.2 6.1	CUT 93	$\frac{40}{32}$	$\frac{1}{0}$	"	"	-	GAB 3'	$\frac{1}{100}$	-	-	-	A 41	A 12	A 2.2	-	PMC 4500	$\frac{\text{TTSC}}{50}$	$\frac{(\text{WF})}{(77)}$		"	"
69	15.2 6.1	CUT 93	$\frac{38}{32}$	$\frac{1}{0}$	"	"	-	GAB 3'	$\frac{1}{100}$	-	-	-	A 83	A 25	A 4.5	-	DAVIS 4500	-	CON-WED		"	"

TABLE B-4 (CONTINUED)

A.	PLOT DESCRIPTIONS							B. MECHANICAL STABILIZATION			C. PLANTS		D.	SEEDING						E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. Bef./Aft.	5 O.H. Bef./Aft. (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. $(\frac{m^3}{\%})$	11 Watt-ling $(\frac{rows}{m})$	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre (Type)/Kg/H	18 Straw Kg/H	19 Straw Tack (Type)/Kg/H	20 Other Treat-ment	21 Type	22 Rate kg/ha
70	15.2 6.1	CUT 93	$\frac{38}{35}$	$\frac{1}{0}$	"	"	-	GAB 3'	$\frac{1}{100}$	-	-	-	A 41	A 12	A 2.2	II-1 2800	-	-	-	16-20	280
71	15.2 7.6	CUT 116	$\frac{41}{38}$	$\frac{1}{0}$	"	"	-	GAB 3'	$\frac{1}{100}$	-	-	-	"	"	"	-	-	-	EXCEL	"	"
72	15.2 7.6	CUT 116	$\frac{40}{36}$	$\frac{1}{0}$	"	"	-	GAB 3'	$\frac{1}{100}$	-	-	-	"	"	"	II-3 2800	-	-	-	"	"
73	15.2 6.1	CUT 93	$\frac{40}{38}$	$\frac{1}{0}$	MsG	N	-	GAB 0.9	$\frac{1}{100}$	-	-	-	C 43	C 11	C 0.1	-	DAVIS 4500	$\frac{\text{DOW1}}{755}$	-	"	"
74	15.2 6.1	CUT 93	$\frac{42}{38}$	$\frac{2}{0}$	"	"	-	"	$\frac{2}{100}$	-	-	-	"	"	"	-	"	$\frac{\text{DOW2}}{755}$	$\frac{\text{(WF)}}{(230)}$	"	"
75	15.2 6.1	CUT 93	$\frac{45}{38}$	$\frac{2}{0}$	"	"	-	"	$\frac{2}{100}$	-	-	-	"	"	"	-	"	$\frac{\text{DOW3}}{755}$	$\frac{\text{(WF)}}{(460)}$	"	"
76	15.2 6.1	CUT 93	$\frac{40}{38}$	$\frac{1}{0}$	"	"	-	"	$\frac{1}{100}$	-	-	-	C 86	C 22	C 0.2	-	"	$\frac{\text{WF}}{1120}$	-	"	"
77	15.2 6.1	CUT 93	$\frac{46}{35}$	$\frac{4}{0}$	"	"	-	GAB 1.8	SEE TABLE B-VI SECTION H												
78	15.2 6.1	CUT 93	$\frac{52}{35}$	$\frac{4}{0}$	"	"	-	GAB 2.8	"												
79	15.2 6.1	CUT 93	$\frac{50}{35}$	$\frac{4}{0}$	"	"	-	"	"												

TABLE B-4 (CONTINUED)

A.	PLOT DESCRIPTIONS							B. MECHANICAL STABILIZATION			C. PLANTS		D.		SEEDING					E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. $\frac{\text{Bef.}}{\text{Aft.}}$	5 O.H. $\frac{\text{Bef.}}{\text{Aft.}}$ (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. ($\frac{m^3}{I}$)	11 Wattling ($\frac{\text{rows}}{m}$)	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre $\frac{\text{(Type)}}{\text{Kg/H}}$	18 Straw Kg/H	19 Straw Tack $\frac{\text{(Type)}}{\text{Kg/H}}$	20 Other Treatment	21 Type	22 Rate kg/ha
80	15.2 7.6	CUT 116	$\frac{45}{35}$	$\frac{3}{0}$	MsC	NE	-	GAB 1.8	SEE TABLE B-VI SECTION H												
81	15.2 7.6	CUT 116	$\frac{39}{34}$	-	MsC	"	-	GAB .9	-	-	50	SHRB	A 41	A 12	A 2.2	III-3 2800	-	-	-	16-20	280
82	15.2 7.6	CUT 116	$\frac{40}{37}$	-	"	"	-	"	-	-	50	SHRB	A 83	A 25	A 4.5	III-3 2800	-	-	-	"	"
83	15.2 7.6	CUT 116	$\frac{37}{35}$	-	"	"	-	"	-	-	-	-	C 86	C 21	C 0.2	-	DAVIS 4500	$\frac{\text{DOW1}}{755}$	-	"	"
84	15.2 7.6	CUT 116	$\frac{37}{34}$	-	"	"	-	"	-	-	-	-	"	"	"	-	"	$\frac{\text{DOW2}}{755}$	$\frac{\text{(WF)}}{\text{(230)}}$	"	"
85	15.2 9.1	CUT 139	$\frac{40}{34}$	-	"	"	-	"	-	-	-	-	"	"	"	-	"	$\frac{\text{DOW3}}{755}$	$\frac{\text{(WF)}}{\text{(460)}}$	"	"
86	15.2 6.1	CUT 93	$\frac{40}{34}$	-	"	"	-	"	-	-	10 40	SHRB GRS	A 83	A 25	A 4.5	III-3 5600	-	-	-	"	"
87	15.2 6.1	CUT 93	$\frac{45}{34}$	-	"	E	-	"	SEE TABLE B-VI SECTION J												
88	15.2 7.6	CUT 116	$\frac{40}{34}$	$\frac{4}{0}$	"	"	-	GAB 1.8	"												
89	15.2 7.6	CUT 116	$\frac{53}{34}$	$\frac{8}{8}$	"	SE	-	GAB 2.8	"												
90	15.2 7.6	CUT 116	$\frac{55}{34}$	$\frac{8}{8}$	"	"	-	"	"												

TABLE B-4 (CONTINUED)

A. PLOT DESCRIPTIONS								B. MECHANICAL STABILIZATION			C. PLANTS		D. SEEDING							E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. $\frac{\text{Bef.}}{\text{Aft.}}$	5 O.H. $\frac{\text{Bef.}}{\text{Aft.}}$ (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. ($\frac{m^3}{\%}$)	11 Watt-ling $\frac{\text{(rows)}}{m}$	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre $\frac{\text{(Type)}}{\text{Kg/H}}$	18 Straw Kg/H	19 Straw Tack $\frac{\text{(Type)}}{\text{Kg/H}}$	20 Other Treat-ment	21 Type	22 Rate kg/ha
91	15.2 3.0	CUT 46	$\frac{40}{34}$	-	MsG	SE	-	-	-	-	-	-	A 41	A 12	A 2.2	-	DAVIS 4500	$\frac{\text{TTII}}{100}$	$\frac{\text{(WF)}}{(336)}$	"	"
92	15.2 4.6	CUT 70	$\frac{40}{34}$	-	"	"	-	-	-	-	-	-	A 83	A 25	A 4.5	II-3 5600	-	-	-	"	"
93	15.2 3.0	CUT 46	$\frac{40}{34}$	-	"	"	-	-	-	-	-	-	"	"	"	-	PMC 4500	$\frac{\text{TTSC}}{50}$	$\frac{\text{(WF)}}{(77)}$	"	"
94	15.2 6.1	CUT 93	$\frac{38}{36}$	-	"	N	-	CURB 0.3	-	-	100	BOTH	A 41	A 12	A 2.2	I-3 2800	-	-	-	"	"
95	15.2 9.1	CUT 139	$\frac{38}{36}$	-	"	"	-	"	-	-	140	BOTH	"	"	"	I-1 2800	-	-	-	"	"
96	15.2 7.6	CUT 116	$\frac{38}{37}$	$\frac{7}{2}$	"	"	-	"	$\frac{5}{71}$	-	50 200	GRS SHRB	A 83	A 25	A 4.5	II-3 5600	-	-	-	"	"
97	15.2 6.1	CUT 93	$\frac{38}{36}$	$\frac{7}{2}$	"	"	-	"	$\frac{5}{71}$	-	50 175	GRS SHRB	A 41	A 12	A 2.2	II-3 2800	-	-	-	"	"
98	15.2 7.0	CUT 107	$\frac{38}{35}$	$\frac{4}{2}$	"	"	-	"	$\frac{2}{50}$	-	-	-	A 83	A 25	A 4.5	-	DAVIS 4500	$\frac{\text{TTII}}{100}$	$\frac{\text{(WF)}}{(336)}$	"	"
99	15.2 6.1	CUT 93	$\frac{37}{35}$	$\frac{1}{0}$	"	"	-	"	$\frac{1}{100}$	-	-	-	C 86	C 21	C 0.2	-	-	-	HG 1010	"	"
100	15.2 6.1	CUT 93	$\frac{37}{35}$	$\frac{4}{1}$	"	"	-	"	$\frac{3}{75}$	-	-	-	"	"	"	-	-	-	HG 1410	"	"
101	15.2 4.6	CUT 70	$\frac{37}{35}$	$\frac{10}{2}$	"	"	-	"	$\frac{8}{80}$	-	-	-	A 83	A 25	A 4.5	-	-	-	EXCEL	"	"

TABLE B-4 (CONTINUED)

A. PLOT DESCRIPTIONS								B. MECHANICAL STABILIZATION			C. PLANTS		D. SEEDING							E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. $\frac{\text{Bef.}}{\text{Aft.}}$	5 O.H. $\frac{\text{Bef.}}{\text{Aft.}}$ (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. $(\frac{m^3}{\%})$	11 Watt-ling $\frac{(\text{rows})}{m}$	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre $\frac{(\text{Type})}{\text{Kg/H}}$	18 Straw Kg/H	19 Straw Tack $\frac{(\text{Type})}{\text{Kg/H}}$	20 Other Treat-ment	21 Type	22 Rate kg/ha
102	15.2 4.6	CUT 70	$\frac{38}{36}$	$\frac{10}{2}$	"	"	-	"	$\frac{8}{80}$	-	-	-	A 41	A 12	A 2.2	-	PMC 4500	$\frac{\text{TTSC}}{50}$	$\frac{(\text{WF})}{(77)}$	16-20	280
103	21.3 6.1	CUT 93	$\frac{45}{40}$	$\frac{4}{1}$	"	"	-	"	$\frac{3}{75}$	-	-	-	"	"	"	-	DAVIS 4500	$\frac{\text{TTII}}{100}$	$\frac{(\text{WF})}{(336)}$	"	"
104	15.2 6.1	CUT 93	-	-	"	"	-	"	-	-	-	-	-	-	-	-	-	-	-	"	"
105	15.2 4.6	CUT 70	$\frac{36}{32}$	-	"	"	-	"	-	-	20 100	GRS SHJRB	A 41	A 12	A 2.2	I 2800	-	-	-	"	"
106	15.2 3.7	CUT 56	$\frac{30}{26}$	-	"	"	-	"	-	-	20 100	GRS SHRB	A 83	A 25	A 4.5	I 5600	-	-	-	"	"
107	15.2 3.7	CUT 56	$\frac{40}{40}$	-	"	"	-	"	-	-	-	-	B 105	B 4.5	B 2.2	"	-	-	-	"	"
108	15.2 4.6	CUT 70	$\frac{40}{40}$	-	"	"	-	"	-	-	-	-	"	"	"	"	-	-	-	"	"
109	15.2 6.1	CUT 93	$\frac{55}{35}$	-	MsG	NW	-	GAB 1.8	SEE TABLE B-VI SECTION E												
110	15.2 7.6	CUT 116	$\frac{55}{35}$	-	"	"	-	"	"												
111	15.2 6.1	CUT 93	$\frac{50}{35}$	-	"	"	-	"	"												

TABLE B-4 (CONTINUED)

A. PLOT DESCRIPTIONS								B. MECHANICAL STABILIZATION			C. PLANTS		D. SEEDING							E. FERTILIZER	
1 No.	2 Dim. (m) (m)	3 Type Area (m^2)	4 Deg. $\frac{\text{Bef.}}{\text{Aft.}}$	5 O.H. $\frac{\text{Bef.}}{\text{Aft.}}$ (m^3)	6 Soil Type	7 Exp.	8 Seep (%)	9 Toe	10 O.H. ($\frac{m^3}{\%}$)	11 Wattling ($\frac{\text{rows}}{m}$)	12 No	13 Type	14 Grs. Kg/H	15 Leg. Kg/H	16 Shr. Kg/H	17 Wood Fibre $\frac{\text{(Type)}}{\text{Kg/H}}$	18 Straw Kg/H	19 Straw Tack $\frac{\text{(Type)}}{\text{Kg/H}}$	20 Other Treatment	21 Type	22 Rate kg/ha
112	15.2 3.0	CUT 46	$\frac{34}{34}$	-	"	NE	-	"		-	-	-	A 83	A 25	A 4.5	-	DAVIS 4500	$\frac{\text{TTII}}{100}$	$\frac{\text{(WF)}}{(336)}$	"	"
113	15.2 4.6	CUT 70	$\frac{34}{34}$	$\frac{1}{0}$	"	"	$\frac{1}{100}$	"	$\frac{1}{100}$	-	-	-	C 86	C 21	C 0.2	-	"	-	JUTE	"	"
114	15.2 3.7	CUT 56	$\frac{40}{38}$	$\frac{1}{0}$	"	"	$\frac{1}{100}$	"	$\frac{1}{100}$	-	-	-	A 41	A 12	A 2.2	-	"	-	CON- WED	"	"
115	15.2 3.7	CUZ 56	$\frac{40}{38}$	$\frac{2}{0}$	"	"	$\frac{2}{100}$	"	$\frac{2}{100}$	-	190	SHRB	-	-	-	-	-	-	-	"	"
116	15.2 3.7	CUT 56	$\frac{38}{36}$	$\frac{6}{0}$	"	"	$\frac{6}{100}$	"	$\frac{6}{100}$	-	-	-	C 86	C 21	C 0.2	-	DAVIS 4500	$\frac{\text{WF}}{1120}$	-	"	"
117	10.7 3.7	CUT 39	$\frac{36}{36}$	$\frac{6}{0}$	"	"	$\frac{6}{100}$	"	$\frac{6}{100}$	-	-	-	"	"	"	-	"	"	-	"	"

TABLE B-5

PLOT DESCRIPTION SYMBOLS

Note: This table identifies the meaning of those symbols used to describe the plots in columns 1 through 23 of Table B-3 (Northstar Plot Descriptions) and Table B-4 (Rubicon Properties Plot Descriptions).

A. PLOT DESCRIPTIONS

Column 1. Plot Identification Number. Corresponds to number in Figure B-3 and Figure B-4.

Column 2. Plot Dimensions

Top - Width, meters
Bottom - Slope length, meters

Column 3. Plot Type and Area

Top, cut or fill
Bottom, area, square meters

Column 4. Plot Slope Angle

Top - Angle of slope before implementation of erosion control, degrees
Bottom - Angle of slope after erosion control measures, degrees.

Column 5. Plot Overhang Description

For the purposes of this table, "Overhang" means all material above an imaginary 45 degree plane transecting the steepest uppermost portion of the cuts.

Top - Amount of soil in overhang, meters^3 before erosion control implemented
Bottom - Estimated amount of soil remaining in overhang after erosion control implemented.

Column 6. Plot Soil Type (Soil Conservation Service Classification)

MsG - Meeks very stony loamy coarse sand, 30 - 60% slope
DG - Decomposing granite
JTF - Jorge - Tahoma Association, 30 - 50% slopes
H-P - Hardpan layers producing seepage areas

If more than one type is listed, the first is the more prevalent type.

TABLE B-5 (continued)

Column 7. Plot Exposure. The directional exposure of the plot face. N denotes north, E denotes east, S denotes south, and W denotes west.

Column 8. Plot Seepage. The percentage of the slope that is affected by seepage during late spring and early summer.

B. MECHANICAL STABILIZATION

Column 9. Slope Toe Stabilization.

Top-type of toe stabilization.

ROCK - Rockwall of .5 to 1.5 meter diameter boulders
GAB - Rockfilled wire mesh gabion baskets
CURB - Roll curb and gutter

Note: Gutters were constructed at foot of all rockwalls and gabions. No toe stabilization on fill slopes.

Bottom - height of stabilizing structure

Column 10. Slope Overhang Stabilization.

Top - amount of soil removed from overhang (m^3)
Bottom - percent of total overhang removed.

Column 11. Willow Wattling.

Top - Number of rows of wattling
Bottom - Total length of wattling in meters.

C. PLANTS

Column 12. Number of Each Type of Plant

Column 13. Transplant Type

GRS - Container grown grass seedlings
SHRB - Container grown shrubs. Unless otherwise indicated, all shrubs were obtained from the Dept. of Env. Horticulture, U. C. Davis.
(HO) - Plants obtained locally
TRS - Bare root trees purchased from the California State Division of Forestry.

TABLE B-5 (continued)

D. PLOT SEEDING

Column 14. Grass Seeding Rate, kg/ha.

Column 15. Legume Seeding Rate, kg/ha.

Column 16. Shrub Seeding Rate, kg/ha.

Letters A-E in Columns 15-17 indicate seed mixtures as follows. The top one-quarter of all plots at Rubicon Properties was hand seeded with grass mixture "C" at a rate of approximately 50 kg/ha after application of final mulch or netting.

PERCENTAGE COMPOSITION OF SEED AND FERTILIZER MIXTURES USED AT THE EROSION CONTROL PROJECT SITES

GRASSES	Grass Seed Mixtures				
	A	B	C	D	E
Luna pubescent wheatgrass	11	11	16	40	25
Tegmar intermediate wheatgrass	66	56	42	40	25
Durar hard fescue	17	--	16	--	12
Potomac orchard grass	--	33	16	20	25
Manchar smooth brome	6	--	--	--	--
Lincoln smooth brome	--	--	10	--	13
	100	100	100	100	100

LEGUMES	Legume Seed Mixtures				
	A	B	C	D	E
Lutana cicer milkvetch	57	50	67	50	--
Dutch white clover	24	50	11	50	100
Cascade trefoil	19	--	22	--	--
	100	100	100	100	100

TABLE B-5 (continued)

SHRUBS AND WILDFLOWERS	Shrub Seed Mixtures			
	A	B	C	D
Artemisia tridentata	10	100	100	--
Purshia tridentata	30	--	--	10
Oenotheria hookeri	20	--	--	10
Linum lewisii	10	--	--	--
Gilia leptantha	10	--	--	--
Nemophila maculata	10	--	--	--
Eschcholzia calif.	10	--	--	30
Eriogonum umbellatum	--	--	--	60
	100	100	100	100

Column 17. Wood Fiber Mulch.

Top - Type of mulch and method of seed application.

I - Weyerhauser "Silva-Fiber"^{R}
II - Conwed Hydro Mulch^{R}
III - Conwed Hydro Mulch "2000"^{R}
1 - Seed in mulch
2 - Hydroseeded, then mulched
3 - Hand seeded and raked in, then mulched

Bottom - Rate of mulch application, kg/ha

Column 18. Straw Mulch.

Top - Type of straw applied

DAVIS - Barley straw
PMC - Tall wheatgrass
BOTH - PMC in upper part of plot. DAVIS in lower part.
RICE - Rice straw
WHEAT - Wheat straw

Note: Seed hand cast and hand raked on all straw plots.

Bottom - Rate of straw application, kg/ha

Column 19. Straw Tack.

Top - Type of straw tack applied

SSEC - Sta-Soil Ecology Control^{R}
TT II - Terra Tack II^{R}
TTSC - Terra Tack II^{R}, super concentrate

TABLE B-5 (continued)

Column 19. (continued)

WF - Woodfiber
PVA - Polyvinyl acetate (used to tack wood fiber mulch only)
DOW (1,2,3,X) - DOW Chemical USA XFS - 4163 L mulch binder applied as indicated below:

DOW MULCH BINDER APPLICATION RATES

	Water kg/ha	Latex kg/ha	Modifier kg/ha	Wood Fiber kg/ha
DOW 1	4.25	.77	10.2	---
DOW 2	4.25	.77	10.2	230
DOW 3	4.25	.77	10.2	460
DOW X	8.50	1.54	20.4	460

Note: DOW XFS - 4163 L mulch binder is a form of Styreme butadiene (SBR).

Bottom - Straw tack application rate, kg/ha

Column 20. Other Materials Used to Stabilize Seeded Slopes

EXCEL - Excelsior^{R} netting
CONWED - Conwed^{R} plastic netting
HG - Hold-Gro^{R} netting
JUTE - Jute netting

E. FERTILIZER

Column 21. Type of Fertilizer Applied.

16-20-0 - Commercial fertilizer
M-A - Mag-Amp^{R} 7-40-6 slow release
U-F - Urea formaldehyde 38-0-0 slow release

Column 22. Rate of Fertilizer Application, kg/ha

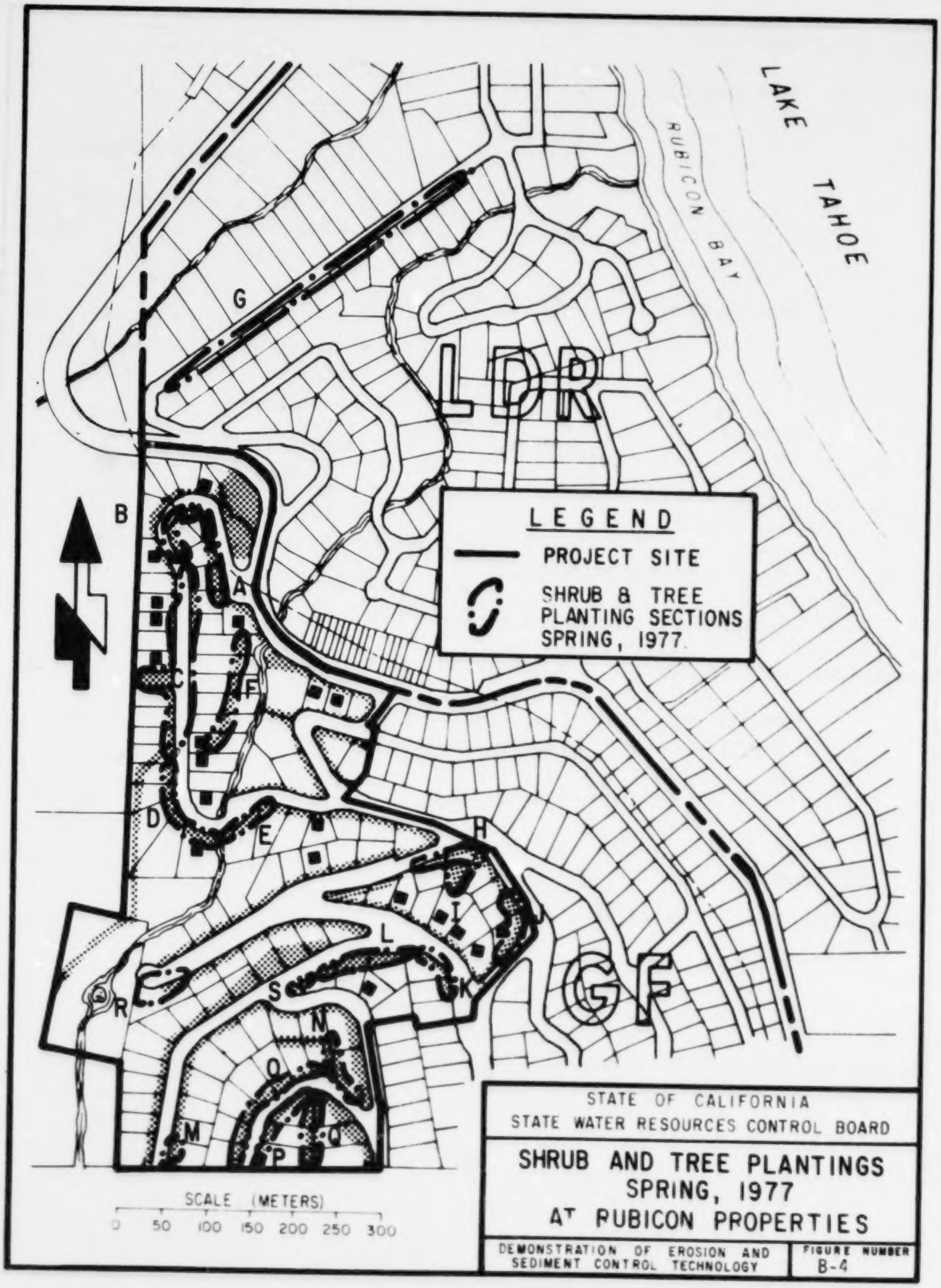

LAKE TAHOE
RUBICON BAY
LDR
GF
G
B
A
C
F
D
E
H
I
L
K
S
R
N
O
M
P
Q
LEGEND
PROJECT SITE
SHRUB & TREE PLANTING SECTIONS SPRING, 1977.
SCALE (METERS)
0 50 100 150 200 250 300
STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD
SHRUB AND TREE PLANTINGS SPRING, 1977 AT RUBICON PROPERTIES
DEMONSTRATION OF EROSION AND SEDIMENT CONTROL TECHNOLOGY
FIGURE NUMBER
B-4

TABLE B-6

RUBICON PROPERTIES SHRUB PLANTING SECTION DESCRIPTION - MAY, JUNE 1977

Section A: East facing cut slope adjacent to Rubicon Glen Drive. Planted 6/3/77.

160 Atriplex canescens
160 Ceanothus prostratus
120 Rhamnus rubra
120 Penstemom strictus

Note: Spacing is variable. Planted as listed above right to left facing slope from road surface. Propagated in various containers. Fertilized with various fertilizer treatments.

Section B: North and west facing cut slope adjacent to Rubicon Glen Drive. 2-3 rows of wattling at south end of section. Planted 6/23/77.

600 ± willow stakes driven in at random over entire plot.

Section C: East and west facing cut slopes adjacent to Rubicon Glen Drive. Planted 6/3/77.

350 Abies concolor, Abies magnifica, Pinus jeffreyi (bare root) various pines and firs (bare root)
280 Penstemon newberryi
50 Erigonum umbellatum
440 Agropyron trichophorum "Luna" (peat pots)
80 Atriplex canescens

Note: Above planted at random within Section C.

Section D: East to north facing cut slope adjacent to Rubicon Glen Drive and Lonely Gulch Creek. Planted 5/24/77 and 6/3/77.

120 Agropyron trichophorum "Luna" (peat pots)
80 Penstemon newberryi
160 Chrysothamnus nauseousus
±300 Willow stakes

Note: Above planted at random within Section D.

Section E: Northwest facing cut slope adjacent to Rubicon Glen Drive and Lonely Gulch Creek. One and two tier gabion breastwall constructed behind curb and gutter at slope toe. Slope scaled, overhangs removed with three to four rows of willow wattling. Planted 6/2/77.

TABLE B-6 (continued)

Section E (continued):

100 Pinus jeffreyi
280 Agropyron trichophorum "Luna" (peat pots and books)

Note: Jeffrey pines planted in fertilizer test plots.

Section F: Abandoned dirt road adjacent to Lonely Gulch Creek. Planted 5/11, 12, 13, 24/77.

500 Pinus jeffreyi (bare root)
275 Pinus lambertiana (bare root)
120 Purshia tridentata (books)
120 Ceanothus prostratus (books)
120 Chrysothamnus nauseosus (peat pots)
20 Cornus stolonifera (deep tubes)
40 Penstemon strictus (peat pots)
40 Symphoricarpos sp. (peat pots)
40 Prunus emarginata (peat pots)
20 Penstemon newberryi (deep tubes)

Above planted in fertilizer test plots and container comparison plots.

Section G:

160 Agropyron trichophorum "Luna" (peat pots)
213 Penstemon newberryi
603 Prunus emarginata
55 Penstemon strictus
60 Atriplex canescens
40 Lupinus sp.
60 Rhamnus rubra
90 Ribes sp.
68 Ceanothus prostratus
16 Cornus stolohifera
15 Eriogonum umbellatum
48 Salix sp.

Planted in blocks by species.

Section H: Severe north facing cut slope adjacent to Lower Lakeview Drive. Two and three tier gabion retaining wall constructed behind curb and gutter at slope toe. Slope extensively scaled and overhangs removed with four to six rows of contour willow wattling. Planted 6/3/77.

66 various Lupinus species
400 Agropyron trichophorum "Luna" (peat pots)
80 Penstemon newberryi

TABLE B-6 (continued)

Section H (continued):

Note: *Lupinus* species planted with various fertilizer treatments. Other plants at random. Partially replanted on 6/20 with ± 200 "Luna" and *Penstemon newberryi*.

Section I: Cleared lot above Section H adjacent to North Lakeview Drive. Planted 5/24/77.

120 *Agropyron trichophorum* "Luna" (peat pots)
240 *Atriplex canescens* (book planters)
150 *Abies concolor* (bare root)

Note: "Luna" and Atriplex planted in fertilizer test plots.

Section J: Severe east facing cut slope at corner of Lakeview and Manzanita Drives. Two and three tier gabion retaining wall constructed behind curb and gutter at slope toe on southerly two-thirds of this section. Planted 6/1, 3/77.

140 *Eriogonum umbellatum*
100 *Pinus labertiana* and *Pinus jeffreyi* (bare root)
80 *Atriplex canescens*
40 *Chrysothamnus nauseousus*

Note: Erigonum on northerly 15 meters of section with various fertilizer treatments.

Section K: East facing cut slope adjacent to Upper Lakeview Drive. Planted 5/24/77.

250 *Penstemon newberryi* (small tubes north end)
280 *Agropyron trichophorum* "Luna" (south end)

Section L: North facing cut slope adjacent to Forest Drive. Four rows of contour willow wattling. Entire slope extensively scaled with overhang removed. Curb and gutter reconstructed at slope toe.

390 *Penstemon newberryi*
280 *Agropyron trichophorum* "Luna"
240 *Chrysothamnus nauseousus*
75 various *Abies* species
400 willow (*Salix*) stakes
200 *Atriplex canescens*

Note: Above planted in fertilizer and container test plots.

TABLE B-6 (continued)

Section M: North facing cut slope at the end of Forest Drive. Overhang removed and 3-4 rows of contour wattling placed at 2 meter intervals.

80 Penstemon newberryi
52 Chrysothamnus nauseosus
42 Purnus emarginata
123 Atriplex canescens
67 Ceanothus prostratus
10 Symphoricarpos sp.
60 Purshia tridentata
21 Rhamnus rubra
22 Arctostaphylos patula

Plants listed above planted at random below wattled cut and on adjacent cuts.

250 Penstemon newberryi
160 Ceanothus prostratus
280 Purshia tridentata
180 Chrysothamnus nauseosus

Plants listed above planted in fertilizer test plots on wattled cut.

Section N: Abandoned dirt road from Highland Drive. Water bar and grass seeding conducted in fall 1976. Planted 6/1/77.

400 Agropyron trichophorum "Luna"

Note: "Luna" in peat pots placed southerly portion adjacent to Highland Drive.

Section O: Northwest facing fill slope adjacent to Highland Drive. Planted 6/1/77.

250 Pinus lambertiana and P. jeffreyi (bare root)

Section P: Northwest facing cut slope adjacent to Highland Drive. Four rows of willow wattling on southerly portion. Planted 5/27/77.

360 Agropyron trichophorum "Luna" (book planters)
125 Pinus jeffreyi (bare root)
125 Pinus lambertiana (bare root)

Note: "Luna" on northerly portion of section and Pinus spp planted in fertilizer test plots.

TABLE B-6 (continued)

Section Q: East and west facing cut slopes adjacent to dirt road leading to water storage tank from Highland Drive. Planted 6/1/77.

250 *Pinus lambertiana* and *P. jeffreyi* (bare root)

Section R: North facing gentle slope with a portion of cut and a portion of an old road. Planted 6/15/77.

240 *Prunus emarginata*
280 *Purshia tridentata*
160 *Ceanothus prostratus*

These planted in fertilizer test plots.

Area adjacent to test plots planted with ± 400 container grown grasses and shrubs.

APPENDIX C

WATER QUALITY AND ENVIRONMENTAL MONITORING DATA

Number

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TABLES

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APPENDIX C

WATER QUALITY AND ENVIRONMENTAL MONITORING DATA

INTRODUCTION

The material in Appendix C is a more extensive presentation of much of the hydrologic and water quality data which is only briefly referred to Section VII of the main report. Included on the following pages are the following Tables:

Table C-1:	Water Stored as Snow for each 105 Meter (500 Feet) Contour Interval at Northstar. Presented is a summarization of the water content of snow pack measurements taken at six sampling sites at Northstar during 1975 and 1976. The original data at each site is assumed to be representative of conditions found in succeeding 150 meter contour intervals from the lowest elevation of the Northstar development to the top of Mt. Pluto. Estimate of total water content of snow pack at each sampling date is also included.
Table C-2:	Suspended Sediment Sampling Site Locations in West Martis Creek Watershed. Presented is a brief description of suspended sediment sampling stations located in the West Martis Creek (Northstar) watershed. Included is description of drainage area above sampling site listing types of disturbances, if any.
Table C-3:	Summarized Suspended Sediment Data Collected at Northstar October 1974 through September 1976. Presented is a summarization of the suspended sediment samples collected at Northstar at each sampling site for each runoff type: Lowflow, Stage I Snowmelt, Stage II Snowmelt, and Rainfall. A total of 571 samples were collected and analyzed.
Table C-4:	Suspended Sediment Sampling Site Locations in Lonely Gulch Creek Watershed. Presented is brief description of suspended sediment sampling stations located in the Lonely Gulch Creek (Rubicon Properties) Watershed.

Table C-5:	Summarized Suspended Sediment Data Collected at Lonely Gulch Creek (Rubicon Properties) October, 1972 through September, 1976. Presented is a summarization of the suspended sediment samples collected at Northstar at each sampling site for each runoff type: Lowflow, Stage I Snowmelt, Stage II Snowmelt, and Rainfall. A total of 301 samples were collected and analyzed.
Table C-6:	Standing Crop Estimates (number of individuals/m^2) of Benthic Macroinvertebrates listed by Family for West Martis Creek (Northstar) for all Stations Sampled during 1974, 1975 and 1976. Summarized data for nine sampling stations in West Martis Creek.
Table C-7:	Same as above for four stations in Lonely Gulch Creek (Rubicon Properties) during 1975 and 1976.
Table C-8: (through Table C-13:)	Summarized Monthly Flows and Suspended Sediment Loads Projected by Water Quality Models. Based upon suspended sediment concentration vs. streamflow relationships, and continuous streamflow records at four West Martis Creek and two Lonely Gulch Creek gaging stations. Estimated suspended sediment loads for the four different runoff types during each month of record, at each gage is presented.

TABLE C-1

WATER STORED AS SNOW FOR EACH 150 METER (500 FEET) CONTOUR INTERVAL AT NORTHSTAR

SNOW PACK WATER CONTENT (TONS X 10^6)

DATE	#1 (0.75 km^2)	#2 (3.33 km^2)	#3 (2.20 km^2)	#4 (4.28 km^2)	#5 (2.44 km^2)	#6 (0.66 km^2)	TOTAL 12.08 km^2)
1-22-75	0.05	0.18	0.45	1.08	0.73	0.27	2.75
2-03-75	0.13	0.66	0.70	1.61	1.06	0.38	4.55
3-06-75	0.16	1.00	1.16	2.52	1.71	0.61	7.16
3-19-75	0.24	1.42	1.53	3.00	2.16	0.72	9.06
4-10-75	0.31	1.86	1.93	3.52	2.48	0.99	11.10
4-30-75	0.27	1.45	1.81	3.89	2.74	0.97	11.15
5-09-75	0.30	1.34	1.86	3.91	2.67	0.91	10.98
5-22-75	--	0.54	1.18	1.82	2.02	0.89	6.47
6-03-75	--	--	--	1.35	1.67	0.74	3.76
6-21-75	--	--	--	--	0.07	0.46	0.54
1-15-76	0.02	0.12	0.20	0.41	0.27	0.17	1.20
2-23-76	--	0.30	0.36	0.67	0.47	0.26	2.07
3-15-76	0.11	0.42	0.60	1.30	0.67	0.36	3.47
3-26-76	0.07	0.44	0.60	1.13	0.78	0.35	3.38
5-03-76	--	--	--	--	0.28	0.29	0.57

NOTE: Refer to Figure VII-1 in Section VII for location of snow courses at Northstar

TABLE C-2

SUSPENDED SEDIMENT SAMPLING SITE LOCATIONS IN WEST MARTIS CREEK WATERSHED

Site 1. Gage No. 1. Stevens gage above 1.22 meter rectangular weir. Located near the Big Springs day lodge on the west fork, West Martis Creek. Drainage area above this point is 294 hectares and extends to the summit of Mount Pluto at an elevation of 2620 meters. Approximately 113 acres of forest land have been cleared for ski trails. Flow over this weir is principally overland flow as spring water is collected via an underground collection system above this point. Groundwater collected by this system is transported either to the water treatment plant or through a bypass mechanism to the V-notch weir (Site 5).

Site 2. Gage No. 2. Stevens gage above a 90° V-notch weir. Located on east fork of West Martis Creek above the confluence with the west fork. The drainage area above this point is 471 hectares. A 2.0 x 105 cubic meter storage reservoir is located 2.4 kilometers above this sampling site. All surface runoff is collected by this reservoir which only briefly overflows in the spring time of some years. A groundwater collection system is located above this reservoir. A bypass valve spills excess water to the east fork about one-third of a mile below the reservoir. Extremely low flows have been observed in the east fork at this point due to the limitation of bypass flow from the groundwater collection system when the treatment plant is on.

Site 3. Gage No. 3. Stevens gage above a 1.83 meter retangular weir. Located on West Martis Creek below a bridge approximately one-eighth mile north of the golf course club house. Samples taken above bridge crossing the creek. Drainage area above this point is 1308 hectares. The majority of the Northstar development is above this point.

Site 4. Gage No. 4. Stevens gage above 1.22 meter retangular weir. Located on unnamed tributary to Martis Creek. Drainage area above this point is 220 hectares. Meadow, pasture, and timber areas are located above this sampling point.

Site 5. V-notch weir. Sixty degree V-notch weir located 1.22 meters east of Gage No. 1. Flow consists of overflow from the Big Springs groundwater collection system. Flows have been seen to range from approximately 30 liters/sec when the treatment plant is not functioning to as low as 2.25 liters/sec when the treatment plant is on.

Site 6. Village Culvert. 1.22 meter CMP draining Northstar Village and parking area. Discharging to the west fork of West Martis Creek about 100 meters NE of the village center. The total draining to the

TABLE C-2 - continued

village culvert is 80 hectares. 70 hectares or 88 percent of the total area does not include any man-made disturbances. The lower 10 hectares of the drainage contains 0.6 hectare of paved roadway, 2.0 hectare of paved parking area, 0.2 hectare of structures, 0.4 hectare of unrevegetated oversteepened cut slopes. These structures, paved roadways, parking lots, and cut slope surfaces drain directly to drop inlets and subsequently to the Village Culvert.

Site 7. West Fork of West Martis Creek just above the discharge point of the Village Culvert.

Site 8. Trapezoidal weir with staff gauge on the west fork of West Martis Creek above the contours with the East Fork. The total drainage area above the T-weir is 560 hectares including the ski area and village center.

Site 9. Overflow or bypass valve from the Sawmill Flat groundwater collection system on the east fork of West Martis Creek at the point where Big Springs Road crosses the creek.

Site 10. East Fork of West Martis directly above Big Springs Road. Surface drainage is apparent at this point only when there is substantial overflow from the reservoir.

Site 11. Drainage from unpaved dirt road into East Fork of West Martis Creek.

Site 12. East fork of West Martis Creek below Big Springs Road and the sawmill valve.

Site 13. Rock lined drainage ditch from Unit 1-B discharging to West Martis Creek about 60 meters below the confluence of the east and west forks. The Unit 1-B drainage area is 4.1 hectare. This drainage area has 0.75 hectare of paved surface area and 0.4 hectare of condominiums. Hence, approximately 28 percent of this drainage basin is covered with impervious surfaces.

Site 14. A drop inlet collecting drainage from the upper reaches of the parking lot across Northstar Drive from the village. The drop inlet is located at the north end of the parking lot near Big Springs Drive. The entire drainage area is 7.7 hectates. The total paved parking lot surface draining to this drop inlet is 0.6 hectare. Cut slopes adjacent to the parking lot area are approximately .22 hectare.

Site 15. A drop inlet collecting drainage from the middle bay of the parking lot across Northstar Drive from the village. Total area of

TABLE C-2 - continued

this drainage is approximately 0.80 hectare. Paved surface area is 0.4 hectare and cut slope surface area is 0.1 hectare. Drainage to this drop inlet eventually flows to the village culvert and subsequently to the west fork of West Martis Creek.

Site 16. A drop inlet collecting drainage from the southwest corner of the upper reach of the parking lot. Total surface area of this drainage basin is 9.3 hectare. Ninety-nine percent of this drainage area is undisturbed. Cut slope area at the lower reach of this drainage basin is 0.06 hectare; paved surface adjacent to the cut surface is 0.08 hectare.

Site 17. Discharge of drainage ditch to the west side of West Martis Creek about 30 meters south of the Northstar Drive. Total area of this drainage is 108 hectare. The only direct discharge from a disturbed area to this drainage ditch is from Site 14. The Goldbend Condominium units of Unit 1-C are also located within this drainage basin, however, any discharge from disturbed areas is spread over undisturbed land.

Site 18. West Martis Creek directly above Site 17 discharge point.

Site 19. Sampling point is at the end of the culvert under Northstar Drive above confluence with rock lined drainage ditch approximately 100 meters west of West Martis Creek. Drainage is surface flow from waste water treatment plant site.

Site 20. Sampling point in rock lined drainage ditch above Site 19.

Site 21. Drainage from Unit 1-A at discharge point to each side of West Martis Creek just above Northstar Drive. Total drainage area is 1.5 hectares. Paved surface area which contributes to the majority of the runoff from this unit is about .26 hectare.

Site 22. West Martis Creek about 30 meters below Northstar Drive.

Site 23. Small unnamed creek about 300 meters east of West Martis Creek just above Northstar Drive.

Site 24. Small unnamed creek about 1,000 meters east of West Martis Creek just below Northstar Drive.

Site 25. Small unnamed creek about 120 meters of West Martis Creek just north of Basque Street.

Site 26. West Martis Creek just north of Basque Street.

TABLE C-2 - continued

Site 27. West Fork of West Martis Creek about 10 meters above the bridge from the village parking lot to the recreation complex.

Site 28. Overland drainage from condominium unit and concentrated across fill slope which forms the ski run at the bottom of the transport lift. Drainage is to the west fork of West Martis Creek at the recreation complex bridge. The total area of this drainage is approximately 10.5 hectares. Fill area comprising the ski run-out area at the bottom of the transport lift about 1.2 hectare. Impervious paved parking lot and street surface areas from which flow is concentrated across the ski run has an areal extent of 0.5 hectare.

Site 29. Middle Martis Creek above confluence with Martis Creek.

Site 30. West Martis Creek just above confluence with Martis Creek.

Site 31. Martis Creek just above confluence with West Martis Creek.

TABLE C- 3 SUMMARIZED SUSPENDED SEDIMENT DATA COLLECTED AT NORTHSTAR, OCTOBER 1974 THROUGH SEPTEMBER 1976

Site and Name	LOWFLOW			STAGE I			STAGE II			RAINFALL		
	SAMPLES	AVERAGE	RANGE	SAMPLES	AVERAGE	RANGE	SAMPLES	AVERAGE	RANGE	SAMPLES	AVERAGE	RANGE
Site 1 Gauge 1	12	4.2	2.0- 9.0	11	37.7	0- 204	5	23.8	4.0- 53.0	7	944	2.0- 4870
Site 2 Gauge 2	13	4.2	1.0- 11.0	27	32.3	1.0- 1.0-	9	18.6	3.0- 54.0	16	53.7	1.0- 392
Site 3 Gauge 3	13	7.9	3.0- 34.0	29	33.0	2.0- 126	10	27.0	6.0- 75.0	20	115	3.0- 606
Site 4 Gauge 4	15	21.23	5.3- 87.0	11	9.2	3.8- 21.0	8	21.9	5.27 95.6	9	66.1	10.6- 229
Site 5 V-Notch	16	10.2	0.0- 40.0	5	13.8	0.0- 48.0	5	3.2	0.0- 16.0	2	5.5	1.0- 10.0
Site 6 Village C.	4	55.2	.24- 215	23	131	.83- 490	5	20.0	12.3- 36.1	11	502	2.6- 1190
Site 7 Above VC	7	7.84	0- 38.6	17	13.6	1.56- 75.7	8	98.0	10.0- 309	13	145	.76- 1480
Site 8 T-Weir	12	5.78	1.0- 11.0	21	205	2.0- 1800	10	70.6	7- 298	9	953	5- 6760
Site 9 Saw-val.	6	.24	0- .8	9	5.5	0- 41.2	6	2.05	0.0- 7.0	4	5.77	0- 11.8
Site 10 Above BBR	1	2.6	2.6	0	-	- -	1	17.8	17.8	0	-	- -
Site 11 BBRd.	2	10.1	1.23- 19.0	0	-	- -	3	2200	229- 4170	2	714	7- 1620

TABLE C-3 (Continued)

Site and Name	LOWFLOW			STAGE I			STAGE II			RAINFALL		
	SAM-PLES	AVERAGE	RANGE	SAM-PLES	AVERAGE	RANGE	SAM-PLES	AVERAGE	RANGE	SAM-PLES	AVERAGE	RANGE
Site 12 Bel. BSRd.	0	-	- -	6	30.9	10.9- 49.3	1	99	99	0	-	- -
Site 13 Unit 1-B	0	-	- -	1	1.7	1.7	2	43.2	33.8- 53.0	0	-	- -
Site 14 PLDI-1	0	- -	- -	2	158	42- 273	5	350	69- 865	5	1580	84- 4770
Site 15 PLDI-2	0	-	- -	1	125	125	0	-	- -	2	3720	340- 7110
Site 16 PLDI-3	0	-	- -	0	-	- -	2	204	35- 384	2	7480	7410- 7560
Site 17 PLDD-1	0	-	- -	3	71.5	4.0- 111	5	126	21.4- 3	2190	5500	320-
Site 18 Ob. RLDD-1	0	-	- -	3	23.5	9.0- 37.4	4	90.5	1.0- 215	3	81.4	44.2- 109
Site 19 BLDD-2	0	- -	- -	0	-	- -	2	26.2	16.7- 35.6	0	-	- -
Site 20 RLDD-3	0	-	- -	0	-	- -	2	19.5	11.1- 18.0	0	-	- -
Site 21 Unit 1-A	0	-	- -	0	-	- -	2	80.2	80.2	0	-	- -
Site 22 W.M.b.NGDr.	0	-	- -	4	22.4	7.4- 31	3	141	33.5- 140	2	397	35.7- 739

TABLE C- 3 (Continued)

Site and Name	LOWFLOW			STAGE I			STAGE II			RAINFALL		
	SAMPLES	AVERAGE	RANGE	SAMPLES	AVERAGE	RANGE	SAMPLES	AVERAGE	RANGE	SAMPLES	AVERAGE	RANGE
Site 23 Gm.Ck.. a ns	0			0			0			0		
Site 24 S.Ck b NS	0			0			1	4.74	4.74	0		
Site 25 S.Ck. a+ Ba	. 3	20.2	0.0-60	0			3	293	7.04-564	0		
Site 26 WM a+ Bas	1	6020	6020	1	39.0	39.0	2	56.2	24.3 88.0	2	86.4	30.8-142
Site 27 WF rec br.	0			3	211	13-310	4	20.6	8.82-41.0	3	2110	21.4-6240
Site 28 T-1 lift	0			1	3080	3080	4	2350	2.1-6090	3	3280	5.2-8340
Site 29 MM a. Marti	7	4.85	1.2-10.8	2	6.47	5.73-7.20	9	48.6	3.0-292	4	15.9	5.1-33.5
Site 30 WM at M	8	40.6	4.4-92.2	4	41.1	11.5-108	5	14.4	10.4-19.7	1	9.8	9.8
Site 31 M a WM	8	6.71	4.7-11.6	1	15	15	8	36.1	3.6-78	3	17.5	5.4-26
TOTALS	126			185			134			126		

TABLE C-4

SUSPENDED SEDIMENT SAMPLING SITE LOCATIONS IN LONELY GULCH CREEK WATERSHED

Site 32 - Above a small reservoir on Lonely Gulch Creek and above all development.

Site 33 - Located 200 meters below Site 32 and just below the small domestic water supply reservoir. It was located upstream of all disturbances and drainages from Rubicon Properties Subdivision. Gage No. 5 flow recorder located here.

Site 34 - Approximately 130 meters downstream of Site 33 at Rubicon Glen Drive and below a third major drainage swale draining the subdivision.

Site 35 - Located 170 meters below Site 34 and immediately above Highway 89 and below a fourth major drainage swale.

Site 36 - Located 800 meters below Site 35 at Gage No. 6 flow recorder and below the majority of Rubicon Properties Subdivision development.

Site 37 - In Lake Tahoe at the mouth of Lonely Gulch Creek and about 180 meters downstream of Site 36.

Site 38 - Brook Street Culvert No. 1 carrying surface drainage from Forest View Drive.

Site 39 - Drainage ditch at lower end of Highland Drive.

Site 40 - Drainage ditch at lower end of Highview Drive.

Site 41 - Brook Street Culvert No. 2 carrying surface drainage from Highland and Highview Drives.

Site 42 - Brook Street Culvert No. 3 carrying drainage from Upper Lakeview Drive.

Site 43 - Brook Street Culvert No. 4 carrying drainage from Upper Lakeview Drive.

Site 44 - Upper Scenic drainage ditch carrying surface drainage from North Lakeview, South Lakeview, Manzanita and Upper Scenic Drives.

TABLE C-5 SUMMARIZED SUSPENDED SEDIMENT DATA COLLECTED AT LONELY GULCH CREEK (RUBICON) OCTOBER 1972 - SEPTEMBER 1976

Site and Name	LOWFLOW			STAGE I			STAGE II			RAINFALL		
	SAMPLES	AVERAGE	RANGE	SAMPLES	AVERAGE	RANGE	SAMPLES	AVERAGE	RANGE	SAMPLES	AVERAGE	RANGE
Site 32 Above Res.	7	1.61	0-4.26	3	25.6	8.2- 57.9	3	17.1	4.1- 25.8	4	73.4	1.4- 255
Site 33 Gage 'A	31	1.23	0-9	30	7.84	0- 31.3	5	1.86	.3- 4	14	5.74	0- 34.4
Site 34 L.G.Rub.Dr.	7	3.02	.4- 10.16	2	27.1	19.9- 34.3	1	7.3	7.3	9	2900	4- 12300
Site 35 L.G.Hwy 89	7	23.2	14.5 42.2	5	2910	.99- 13000	1	136	136	12	2703	53.6- 15200
Site 36 Gage 'B'	28	6.8	0- 136	31	150	0-1650	5	15.9	.5- 59	12	66.8	8- 188
Site 37 L.G. ATL.T	1	113	113	3	27	4-72.7	0	-	- -	1	0	0
Site 38 Brook #1	0	-	- -	7	1150	84- 5080	0	-	- -	9	373	2.34- 2140
Site 39 Highland	0	-	- -	0	-	- -	0	-	- -	6	25,500	190- 55800
Site 40 Highview	0	-	- -	2	2210	315- 4100	0	-	- -	8	64500	631- 231000
Site 41 Brook #2	0	-	- -	2	16900	284- 33500	0	-	- -	19	37400	690- 122000
Site 42 Brook #3	0	-	- -	0	-	- -	0	-	- -	2	3360	342- 5340

TABLE C-5 (Continued)

Site and Name	LOWFLOW			STAGE I			STAGE II			RAINFALL		
	SAM-PLES	AVERAGE	RANGE	SAM-PLES	AVERAGE	RANGE	SAM-PLES	AVERAGE	RANGE	SAM-PLES	AVERAGE	RANGE
Site 43 Brook #4	0	-	- -	0	-	- -	0	-	- -	8	6160	733- 18800
Site 44 U.Scenic	0	-	- -	2	569	569	0	-	- -	13	17300	282- 63200
TOTALS	81			87			15			118		

TABLE C-6

Standing Crop Estimates (number of individuals/m^2) of Benthic Macroinvertibrates Listed by Family for West Martis Creek (Northstar) for All Stations Sampled During 1974, 1975, and 1976

Collection Date:	September 16, 1974									July 31, 1975							
STATION:	WM-1	WM-2	WM-3	WM-4	WM-5	WM-6	WM-7	WM-8	WM-9	WM-2	WM-3	WM-4	WM-5	WM-6	WM-7	WM-8	WM-9
ANTHROPODA																	
INSECTA																	
EPHEMEROPTERA																	
Baetidae	409	108	942	659	755	1396	324	40	69	180	169	90	79	104	403	176	198
Heptageniidae	33	3	180	26	56	121	43	3	243	11	40	137	14		22	191	122
PLECOPTERA																	
Perlidae	8	59	8	59	26	46	30	3	43	22	14	7	11	47	32		
Chloroperlidae	385	11	121	27	75	81	11	33	291	4	4			25	25	54	108
Nemouridae	191	105	363	84	33	113	5	256	1281	65	25	68	7	14		25	43
Peltoperlidae	3	16	22	22		11	3	5	3	18	11	4			7	22	7
Perlodidae														7	11	14	184
Pteronarcidae																	
TRICHOPTERA																	
Psychomyiidae		3				5				11	7	7	7	7	18	112	4
Lepidostomatidae												4					
Rhyacophilidae	5	24	146	35	170	142	904	40	94	11	32	29	68	7	54	22	47
Brachycentridae					3		62		156	4	18	22	4	4	4	7	187
Leptoceridae											29						
Hydropsychidae	8	5	3	5		5	102		589			11			58		83
Limnephilidae	15	58	97	100			8	6	22	140						4	11
DIPTERA																	
Empididae		22	24	56	35	21	3	11	18	7	4	4	4	11		4	11
Chironomidae	923	73	81		100	167	226	65	893	313	68	97	115	90	176	83	202
Culicidae										7	4	11			7		
Simuliidae		11	140	46		4	3	3	13	7	4	7			4	11	
Tipulidae	11		3			8	30	3	105				4	4		4	22
Rhagionidae																	7
Heleidae					5		8	3	102								
Ephydridae	3	16	22	8	3	13		19									
Psychodidae			8			3											

TABLE C-6 (continued)

Collection Date:	September 16, 1974									July 31, 1975							
STATION:	WM-1	WM-2	WM-3	WM-4	WM-5	WM-6	WM-7	WM-8	WM-9	WM-2	WM-3	WM-4	WM-5	WM-6	WM-7	WM-8	WM-9
HEMIPTERA																	
Corixidae															4		
COLEOPTERA																	
Hydrophilidae										7	4	7					
HALIPLIDAE																	
Elmidae	5	89	352	60	223	218	245	92	1251	7	22	50	65	22	533	58	1134
Dytiscidae															4		
NEMATOMORPHA																	
VEJDOSKY																	
GORDIIDA																	
Gordiidae										7	4	11	11		11	18	72
NEMATA																	
SECERNENTEA																	
Rhabditidae	3		24	11	5	3	46	3	5								
ANNELIDA																	
Oligochaeta	869	51	135	86	94	126	78	65	342	4	22	4	29	36	90	94	86
PLATYHELMINTHES																	
TURBELLARIA																	
Tricladida	5	38	67	32	62		43	19		25	72		25	4	115	90	4
MOULLUSCA																	
PELECYPODA																	
HETERODONTA																	
Sphaeriidae		3	126	3	30	57		143	102	25	4		11		7	11	
ARACHNIDA																	
Hydracarina	3	13	27	11	13	5	8	11	5	29	11	4	11		7	4	4
TOTAL NO. OF INDIVIDUALS	2731	619	2917	931	1728	2543	2193	885	5718	785	576	556	461	386	1611	1028	2536
	16	19	21	18	17	21	20	20	20	20	21	19	16	14	22	20	20

TABLE C-6 (continued)

Collection Date:	December 8, 1975									June 3, 1976							
STATION:	WM-1	WM-2	WM-3	WM-4	WM-5	WM-6	WM-7	WM-8	WM-9	WM-2	WM-3	WM-4	WM-5	WM-6	WM-7	WM-8	WM-9
ARTHROPODA																	
INSECTA																	
EPHEMEROPTERA																	
Baetidae	119	126	328	313	234	263	104	50	4	346	569	871	155	274	155	97	162
Heptagenidae	47	7	7		4	112	288	115	47	259	162	65	86	83	50	342	101
PLECOPTERA																	
Perlidae		7	18	22	18	25	54	4		40	7	4	14	7	29	25	
Chloroperlidae	242	36	40	25	40	112	32	36	18	29	4	7	18	32	83	36	
Nemouridae	40	22	14	11	7	7	14	32	18	25	32	11		11		79	
Peltoperlidae	47	4	4		22		4	4	4	7	11	4	29	22	11	90	
Perlodidae	259	25	14	40	14	32	11	25	4	25	32	22		7	11	11	4
Pteronarcidae													4				
TRICHOPTERA																	
Psychomyiidae	14	11	18	29	58	101	18	22	4	18	4	14	32	50	7	32	
Lepidostomatidae											4					14	
Rhyacophilidae	4	25		7	25	22	14	25	25	36		4	108	4	140	58	155
Brachycentridae	4	4			11		29		18		43			61		29	
Leptoceridae																	
Hydropsychidae				4	4	14	29	7	65	4	7	11	7	4	7	7	119
Limnephilidae				4	4	4	4							68			
DIPTERA																	
Empididae	4		14	11	29	155		7	4	7	43	7	101	187	4		4
Chironomidae	3820	554	176	47	220	612	7	29	58	148	11	14	54	187	50	169	22
Culicidae		32			4												
Simuliidae	4	4	4	11		4	25		4							7	18
Tipulidae		18	4	11	4			7	11	4	11						4
Rhagionidae			4		4					4	4						4
Heleidae										4				7			
Ephydridae										7			7		4		

TABLE C-6 (continued)

Collection Date:	December 8, 1975									June 3, 1976							
STATION:	WM-1	WM-2	WM-3	WM-4	WM-5	WM-6	WM-7	WM-8	WM-9	WM-2	WM-3	WM-4	WM-5	WM-6	WM-7	WM-8	WM-9
HEMIPTERA																	
Corixidae						4											
COLEOPTERA																	
Hydrophilidae					11	4	4	7	7							4	
Haliplidae		4	7	4	4	11		7									
Elmidae	7	43	130	65	209	162	36	25	205	25	76	4	101	130	778	86	1109
NEMATOMORPHA																	
VEJDOSKY																	
GORDIIDA																	
Gordiidae		4			4	18	18	22						36			
NEMATA																	
SECERNENTEA																	
RHABDITIDA																	
Rhabditidae											7	4	7	7		4	7
ANNELIDA																	
Oligochaeta	180	4	25	7	61	112	97	83	4	7	43	4	155	191	86	108	65
PLATYHELMINTHES																	
TURBELLARIA																	
Tricladida	68	36	43	40	18	22	29	7			29	43	7	90		122	
MOLLUSCA																	
PELECYPODA																	
HETERODONTA																	
Sphaeriidae					4		4				40			22		4	
ARACHNIDA																	
Hydracarina											25	22		18		14	
TOTAL NO. OF INDIVIDUALS	4836	1002	850	651	1013	1796	821	514	500	995	1164	1104	874	1485	1364	1389	1806
	15	19	17	17	24	20	20	19	17	18	21	16	16	22	14	22	13

TABLE C-6 (continued)

Collection Date:	October 13, 1976							
STATION:	WM-2	WM-3	WM-4	WM-5	WM-6	WM-7	WM-8	WM-9
ANTHROPODA								
INSECTA								
EPHEMEROPTERA								
Baetidae	50	14	54	25	29	58	40	7
Heptagenidae	108	126	65	94	223	558	173	58
PLECOPTERA								
Perlidae	32	14	22	68	18	58	50	
Chloroperlidae	61	14	4	32	22	36	83	14
Nemouridae								
Peltoperlidae	112		7	29		7	76	14
Perlodidae	277	14	76	11	18	14	22	50
Pteronarcidae								
TRICOPTERA								
Psychomyiidae	79	47	47	126	115	18	97	7
Lepidostomatidae				36				
Rhyacophilidae	126	32	4		230	112	745	119
Brachycentridae				4		11		83
Leptoceridae								
Hydropsychidae	36		7	7	4	36	4	133
Limnephilidae			7		4			
DIPTERA								
Empididae	29		7	4	25	4	54	7
Chironomidae	104		14	14	79	101	14	50
Culicidae								
Simuliidae	25		4	122		4		
Tipulidae			4	14		25	14	11
Rhagionidae								
Heleidae		47	4			7	47	
Ephydridae	4	32	11					

TABLE C-6 (continued)

Collection Date:	October 13, 1976							
STATION:	WM-2	WM-3	WM-4	WM-5	WM-6	WM-7	WM-8	WM-9
HEMIPTERA								
Corixidae								
COLEOPTERA								
Hydrophilidae								
Haliplidae								
Elmidae	72	202	270	594	256	274	191	774
NEMATOMORPHA								
VEJDOSKY								
GORDIIDA								
Gordiidae						14	7	
NEMATA								
SECERNENTEA								
RHABDITIDA								
Rhabditidae					7			11
ANNELIDA								
Oligochaetae	97	108	119	446	306	230	266	68
PLATYHELMINTHES								
TURBELLARIA								
Tricladida		14	22			7	4	4
MOLLUSCA								
PELECYPODA								
HETERODONTA								
Sphaeriidae								
ARACHNIDA								
HYDRACARINA								
TOTAL NO. OF INDIVIDUALS	1212	664	748	1662	1336	1578	1887	1410
	15	12	19	16	14	20	17	16

TABLE C-7

Standing Crop Estimates (number of individuals/m^2) of Benthic Macroinvertibrates Listed by Family for Lonely Gulch Creek (Rubicon Properties) for All Stations Sampled During 1975 and 1976

Collection Date:	7-08-75				12-08-75				6-18-76				10-04-76			
STATION:	LG 1	LG 2	LG 3	LG 4	LG 1	LG 2	LG 3	LG 4	LG 1	LG 2	LG 3	LG 4	LG 1	LG 2	LG 3	LG 4
ARTHROPODA																
INSECTA																
EPHEMEROPTERA																
Baetidae	227	104	25	47	54	126	43	29	493	716	814	454	72	4		
Heptagenidae	72	83	14	65	187	569	90	86	320	328	184	536	238	133	14	4
PLECOPTERA																
Perlidae	47	7		4	72	65	11	43	104	36	4	14	115	40	4	
Chloroperlidae	18		4		54	22	4	25	22	7	7	25	54	101	11	7
Nemouridae	43	4			14	4										
Peltoperlidae									4							
Perlodidae	32	4	11	11	7		7	7	61	18	11	36	151	36	11	
Pteronarcidae																
TRICHOPTERA																
Psychomyiidae	97	18	14	14	198	47	25	36	169	79	54	76	220	83	40	
Lepidostomatidae	4															
Rhyacophilidae	22	29		11	36	18		4	299	32	36	43				
Brachycentridae	32				11									4		
Leptoceridae																
Hydropsychidae	22	7	11		47	4			83	4	7	11	32	4	4	
Limnephilidae	400		4		407		7	4					378	18		
DIPTERA																
Empididae					4				7	7		4	11	11	4	4
Chironomidae	155	97	86	47	112	18	11	11	418	155	158	248	65	40	7	4
Culicidae	4	4														
Simuliidae	18		14		7				40	25	18	97	7			
Tipulidae	54				11			4								
Rhagionidae																
Heleidae		4			7	4	4						4	4		
Ephydridae		4			7	36			11	4	11		40	4		

TABLE C-7 (continued)

Collection Date:	7-08-75				12-08-75				6-18-76				10-04-76			
STATION:	LG 1	LG 2	LG 3	LG 4	LG 1	LG 2	LG 3	LG 4	LG 1	LG 2	LG 3	LG 4	LG 1	LG 2	LG 3	LG 4
HEMIPTERA																
Corixidae																
COLEOPTERA																
Hydrophilidae																
Haliplidae																
Elmidae							7				4	4				
Collembola							11									
NEMATOMORPHA																
VEJDOSKY																
GORDIIDA																
Gordiidae	4															
NEMATA																
SECERNENTEA																
RHABDITIDA																
Rhabditidae																
ANNELIDA																
Oligochaeta	230	29	47	54	54		25	14	94	54	58	97	173	14	4	
PLATYHELMINTHES																
TURBELLARIA																
Tricladida	50	4	14		32	36		14				7				
MOLLUSCA																
PELECYPODA																
HETERODONTA																
Sphaeriidae																
ARACHNIDA																
Hydracarina	11			14												
TOTAL NO. OF INDIVIDUALS	1542	398	244	267	1321	945	245	277	2125	1465	1366	1652	1560	496	99	19
	20	14	11	9	19	12	12	12	14	13	13	14	14	14	9	4

TABLE C-8 SUMMARIZED MONTHLY FLOWS AND SUSPENDED SEDIMENT LOADS PROJECTED BY WATER QUALITY COMPUTER MODEL

SITE 1: GAGE NO. 1

WATER YEAR: 1975

WATERSHED: WEST MARTIS CREEK

	LOWFLOW				STAGE 1				STAGE 2				RAINFALL				MONTHLY	TOTALS
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	KL/MO	%	Ton/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	TON/MO
OCT	4248	92	.01778	17	0		0		0		0		392.4	8	.08880	83	4640	.1066
NOV	3950	100	.01653	100	0		0		0		0		0		0		3950	.01653
DEC	0		0		2725	63	.01156	2	0		0		1605	37	.4964	98	4330	.5080
JAN	0		0		3210	100	.01349	100	0		0		0		0		3210	.01349
FEB	0		0		3040	100	.01275	100	0		0		0		0		3040	.01275
MAR	0		0		1452	70	.00612	5	0		0		607.6	30	.1239	95	2060	.1300
APR	0		0		2492	94	.01042	20	0		0		148.3	6	.0417	80	2640	.05212
MAY	0		0		2723	56	.02780	1	2157	44	2.9751	99	0		0		4880	3.003
JUN	3449	3	.0144	21	0		0		91100	82	9.289	24	16630	15	30.15	76	111,000	39.45
JUL	4090	100	.01710	100	0		0		0		0		0		0		4090	.01710
AUG	1161	98	.0049	65	0		0		0		0		19.44	2	.0027	35	1180	.0076
SEP	1364	23	.00565	21	0		0		0		0		4456	77	16.64	100	5800	16.65
	18260		.07616		15640		.08214		93260		12.26		23660		47.54		150800	59.96

TABLE C-8 (Continued)

SITE 1: GAGE NO. 1

WATER YEAR: 1976

WATERSHED: WEST MARTIS CREEK

	LOWFLOW				STAGE 1				STAGE 2				RAINFALL				MONTHLY	TOTALS
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	KL/MO	%	Ton/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	TON/MO
OCT	3226	76	.01365	4	0		0		0		0		994	24	.3481	96	4220	.3618
NOV	1388	38	.00570	5	1975	54	.00832	7	0		0		278	8	.1030	88	3641	.1170
DEC	0		0		2940	100	.01236	100	0		0		0		0		2940	.01236
JAN	0		0		2340	100	.00979	100	0		0		0		0		2340	.009790
FEB	0		0		1950	100	.00817	100	0		0		0		0		1950	.008170
MAR	0		0		1620	100	.00678	100	0		0		0		0		1620	.006780
APR	0		0		1820	26	.01300	25	5050	74	.03964	75	0		0		6870	.05264
MAY	1747	56	.0073	41	0		0		1383	44	.0106	59	0		0		3130	.01790
JUN	494.1	94	.00207	28	0		0		0		0		29.89	6	.0053	72	524.0	.00737
JUL	7.258	9	.0007	70	0		0		0		0		74.54	91	.0003	30	81.80	.0010
AUG	143.2	41	.000068	2	0		0		0		0		203.8	59	.03670	98	347.0	.003738
SEP	2878	98	.00090	9	0		0		0		0		62.04	2	.0089	91	2940	.0098
	9884		.03100		12640		.05842		6433		.05024		1642		.05023		30600	.6420

TABLE C- 9 SUMMARIZED MONTHLY FLOWS AND SUSPENDED SEDIMENT LOADS
PREDICTED BY WATER QUALITY COMPUTER MODEL

SITE 2: GAGE NO. 2

WATER YEAR: 1975

WATERSHED: WEST MARTIS CREEK

	BASEFLOW				STAGE 1				STAGE 2				RAINFALL				MONTHLY	TOTALS
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	TON/MO
OCT	0				0												68630	1.1032
NOV																	41004	.3771
DEC	0		0		56520	85	.9664	75	0		0		10180	15	.3198	25	66700	1.286
JAN	0		0		54600	100	.5245	100	0		0		0		0		54600	.5245
FEB	0		0		46400	100	.2031	100	0		0		0		0		46400	.2031
MAR	0		0		49160	80	.3701	38	0		0		12430	20	.6084	62	61590	.9785
APR	0		0		57930	95	.8730	83	0		0		2871	5	.1890	18	60800	1.063
MAY	0		0		42400	22	3.987	55	0		0		148600	78	3.290	45	191000	7.277
JUNE	[illegible]	2	.0123	4	0		0		156700	90	5.287	88	15200	9	.7209	12	175000	6.020
JUL	65700	100	.2635	100	0		0		0		0		0		0		65700	.2635
AUG	[illegible]	86	.1313	83	0		0		0		0		5524	14	.0276	17	63820	.1589
SEP	[illegible]	84	.1746	48	0		0		0		0		7148	16	.1921	52	44900	.3667
			.5817				6.924				5.287				5.349		940100	19.62

TABLE C-9 (Continued)

SITE [illegible]: GAGE NO. [illegible]

WATER YEAR: 1976 WATERSHED WEST MARTIS CREEK

	LOWFLOW				STAGE 1				STAGE 2				RAINFALL				MONTHLY	TOTALS
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	TON/MO
OCT	50520	58	.2027	8	0		0		0		0		35780	42	2.478	92	86300	2.681
NOV	[illegible]	27	.1032	3	[illegible]	69	3.402	90	0		0		3347	4	.2758	7	89100	3.781
DEC	0		0		89900	100	3.416	100	0		0		0		0		89900	3.416
JAN	0		0		80400	100	2.274	100	0		0		0		0		80400	2.274
FEB	0		0		72900	100	1.864	100	0		0		0		0		72900	1.864
MAR	0		0		48300	100	.1992	100	0		0		0		0		48300	.1992
APR	0		0		14720	23	.1999	49	50280	77	.2090	51	0		0		65000	.4089
MAY	0		0		27160	70	.1092	70	11630	30	.0465	30	0		0		38790	.1557
JUN	18120	95	.07249	95	0		0		0		0		879.9	5	.0035	5	19000	.07599
JUL	17500	90	.07019	90	0		0		0		0		2004	10	.0081	10	19500	.07829
AUG	17300	65	.07113	41	0		0		0		0		9295	35	.104	59	26600	.1751
SEP	32480	89	.1253	44	0		0		0		0		4123	11	.1679	56	36600	.2932
	161600		.6500		393600		11.46		61910		.2557		55430		3.032		672400	15.40

TABLE [illegible] SUMMARIZED MONTHLY FLOWS AND SUSPENDED SEDIMENT LOADS
PREDICTED BY WATER QUALITY COMPUTER MODEL.

[illegible]: CASE NO. [illegible]

WATER YEAR: 1975

WATERSHED: WEST MARTIS CREEK

	LOWFLOW				STAGE 1				STAGE 2				RAINFALL				MONTHLY	TOTALS
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	TON/MO
OCT	[illegible]	92	[illegible]	52	[illegible]	8	1.880	48	0		0		0		0		293000	3.939
NOV	295000	100	2.383	100	0		0		0		0		0		0		295000	2.383
DEC	0		0		235180	75	3.053	44	0		0		76820	25	3.901	56	312000	6.954
JAN	0		0		27100	100	3.623	100	0		0		0		0		27100	3.623
FEB	0		0		243000	100	2.867	100	0		0		0		0		243000	2.867
MAR	[illegible]		[illegible]		[illegible]	78	[illegible]	[illegible]	0		0		78140	22	72.02	73	361000	16.58
APR	0		0		425000	93	18.45	62	0		0		37000	7	11.33	38	457000	29.78
MAY	0		0		383400	26	68.25	54	1087000	74	57.45	46	0		0		1470000	125.7
JUN	46200	6	.3581	1	0		0		586900	82	19.15	68	82880	12	8.462	30	716000	28.33
JUL	190000	100	1.470	100	0		0		0		0		0		0		190000	1.470
AUG	149200	84	1.158	67	0		0		0		0		27840	16	.5611	33	177000	1.720
SEP	143300	69	1.112	8	0		0		0		0		63630	31	12.39	92	267000	13.50
	1092000		8.460		1865000				1674000		76.6		361400		48.66		4992000	236.4

TABLE C-10 (Continued)

SITE 3: GAUGE NO. 3

WATER YEAR: 1976 WATERSHED: WEST MARTIS CREEK

	LOWFLOW				STAGE 1				STAGE 2				RAINFALL				MONTHLY	TOTALS
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	KL/MO	%	Ton/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	TON/MO
OCT	120900	52	.9352	10	0		0		0		0		112100	48	8.685	90	233000	9.620
NOV	59100	28	.4586	20	139000	66	1.076	47	0		0		10780	5	.7600	33	209000	2.295
DEC	0		0		277000	100	3.733	100	0		0		0		0		277000	3.733
JAN	0		0		229000	100	1.779	100	0		0		0		0		229000	1.779
FEB	0		0		171000	100	1.333	100	0		0		0		0		171000	1.333
MAR	0		0		234000	100	2.125	100	0		0		0		0		234000	2.125
APR	0		0		67300	26	1.770	70	182700	73	.7448	30	0		0		250000	2.515
MAY	0		0		0		0		39590	30	.3286	32	91410	70	.7106	68	131000	1.039
JUN	57330	94	.4444	94	0		0		0		0		3467	6	.0269	6	60800	.4713
JUL	46560	92	.3609	92	0		0		0		0		3938	8	.0306	8	50500	.3915
AUG	55610	62	.4313	27	0		0		0		0		33390	38	1.152	73	89000	1.583
SEP	84730	89	.6566	63	0		0		0		0		10570	11	.3905	37	95300	1.047
	420300		3.287		1117000		11.82		222300		1.073		265700		11.76		2030000	

TABLE C-11: SUMMARIZED MONTHLY FLOWS AND SUSPENDED SEDIMENT LOADS PROJECTED BY WATER QUALITY COMPUTER MODEL

SITE 6: GAUGE NO. 6

WATER YEAR: 1975

WATERSHED: Unnamed Tributary to WEST MARTIS CREEK

	LOWFLOW				STAGE 1				STAGE 2				RAINFALL				MONTHLY TOTALS	
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	TON/MO
OCT																	101000	4.034
NOV																	54290	5.918
DEC	0		0		85300	72	2.641	42	0		0		33330	28	3.5270	58	118500	6.167
JAN	0		0		131000	100	4.068	100	0		0		0		0		131000	4.068
FEB	0		0		121000	100	3.761	100	0		0		0		0		121000	3.741
MAR	0		0			76	3.622	18	0		0		37820	24	16.25	82	155000	19.87
APR	0		0		169440	93	5.256	41	0		0		12560	7	7.484	59	182000	12.74
MAY					156300	31	4.844	70	354800	69	2.075	30	0		0		511000	6.919
JUN	18800	12	.5266	25	0		0		120900	76	.4883	23	19311	12	1.2250	52	159000	2.240
JUL	111000	100	3.109	100	0		0		0		0		0		0		111000	3.109
AUG	79010	85	2.208	80	0		0		0		0		13790	15	.5671	20	92800	2.775
SEP	79930	86	2.231	86	0		0		0		0		12770	14	.3575	14	92700	2.588
																	1829000	74.17

TABLE [illegible] SUMMARIZED MONTHLY FLOWS AND SUSPENDED SEDIMENT LOADS
PREDICTED BY WATER QUALITY COMPUTER MODEL.

SITE ID: [illegible]

WATER YEAR: 1973

WATERSHED: LOWELY GULCH CREEK

	LOWFLOW				STAGE 1				STAGE 2				RAINFALL				MONTHLY	TOTALS
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	TON/MO
OCT																		
NOV	[illegible]	[illegible]	[illegible]	[illegible]	1826	[illegible]	.0011	[illegible]	0		0		0		0		25160	.005838
DEC	0		0		21180	100	.02959	100	0		0		0		0		21180	.02959
JAN	0		0		42750	95	.07172	94	0		0		2249	5	.0044	6	45000	.007612
FEB	0		0		38100	100	.06535	100	0		0		0		0		38100	.06535
MAR	0		0		7930	100	.00917	100	0		0		0		0		7930	.00917
APR	0		0		54700	100	.1504	100	0		0		0		0		54700	.1504
MAY	0		0		271300	64	2.313	66	149763	36	1.217	34	0		0		421000	3.530
JUN	[illegible]	20	[illegible]	13	0		0		190000	80	1.110	87	0		0		240000	1.273
JUL	[illegible]	84	[illegible]	83	0		0		0		0		16190	16	.0476	17	103000	.02808
AUG	[illegible]	87	[illegible]	85	0		0		0		0		4044	13	.0071	15	31500	.04753
SEP	11800	100	.01259	100	0		0		0		0		0		0		11800	.01259

TABLE C- 12 (Continued)

SITE ID: GAUGE NO. 5

WATER YEAR: 1974

WATERSHED: LOWELY GULCH CREEK

	LOWFLOW				STAGE 1				STAGE 2				RAINFALL				MONTHLY	TOTALS
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	KL/MO	%	Ton/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	TON/MO
OCT	14070	97	.01573	98									375.6	3	.0004	2	14450	.01613
NOV	20110	63	.04110	71	10770	31	.01334	23					2010	6	.0037	6	32890	.05444
DEC																		
JAN																		
FEB																		
MAR																		
APR																		
MAY																		
JUN																		
JUL																		
AUG																		
SEP																		

TABLE 3-12 (Continued)

SITE ID: GAUGE NO. 3

WATER YEAR: 1975

WATERSHED: LOWELY GULCH CREEK

	LOWFLOW				STAGE 1				STAGE 2				RAINFALL				MONTHLY	TOTALS
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	TON/MO
OCT																		
NOV																		
DEC																		
JAN																		
FEB																		
MAR																		
APR																		
MAY																		
JUN	0		0		197800	38	2.134	41	311700	60	2.926	57	13510	3	.1023	2	523000	5.1623
JUL	237000	100	1.109	100	0		0		0		0		0		0		237000	1.109
AUG	[illegible]	94	.3214	94	0		0		0		0		7163	6	.0188	6	119000	.3402
SEP	58400	92	.1164	91	0		0		0		0		5298	8	.0115	9	63700	.1279
																		6.739

TABLE F- 12 (Continued)

SITE ID: GAUGE NO. 3

WATER YEAR: 1976

WATERSHED: LONELY GULCH CREEK

	BASEFLOW				STAGE 1				STAGE 2				RAINFALL				MONTHLY	TOTALS
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	TON/MO
OCT	83500	33	1.174	19	0		0		0		0		167500	67	5.051	81	251000	6.225
NOV	8710	33	.0111	33	17690	67	[illegible]	67	0		0		0		0		26400	.03393
DEC	0		0		32190	100	.04401	100	0		0		0		0		32190	.04401
JAN	0		0		37100	100	.05361	100	0		0		0		0		37100	.05361
FEB	0		0		39400	100	.0602	100	0		0		0		0		39400	.0602
MAR	0		0		47700	100	.07579	100	0		0		0		0		47700	.07579
APR	0		0		49200	100	.08239	100	0		0		0		0		49200	.08239
MAY	25000	[illegible]	[illegible]	6	25160	32	.0566	5	27840	36	.9125	89	0		0		78000	1.029
JUN	33700	100	.05105	100	0		0		0		0		0		0		33700	.05105
JUL	3768	77	.00368	74	0		0		0		0		1152	23	.0013	26	4920	.00498
AUG	2734	31	.00265	20	0		0		0		0		6026	69	.0103	80	8760	.01295
SEP	2200	61	.002	56	0		0		0		0		1420	39	.0016	44	3620	.0036
	[illegible]		1.305		268000		.3952		27560		.9125		176100		5.064		612,000	7.677

TABLE [illegible] GENERALIZED MONTHLY FLOWS AND SUSPENDED SEDIMENT LOADS PREDICTED BY WATER QUALITY COMPUTER MODEL.

SITE ID: GAUGE NO. 2

WATER YEAR: 1977

WATERSHED: LONELY GULCH CREEK

	UPLAND				STAGE 1				STAGE 2				RAINFALL				MONTHLY	TOTALS
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	TON/MO
OCT																		
NOV	35660	92	.09324	98	3230	8	.00170	2	0		0		0		0		38890	.09494
DEC	0		0		93020	100	14.03	100	0		0		0		0		93020	14.03
JAN	0		0		44088	96	1.415	90	0		0		1812	4	.1653	10	45900	1.580
FEB	0		0		37100	100	.1098	100	0		0		0		0		37100	.1098
MAR	0		0		20300	100	.03236	100	0		0		0		0		20300	.03236
APR	0		0		69900	100	1.423	100	0		0		0		0		69900	1.423
MAY	0		0		236600	55	32.54	51	192400	45	30.80	49	0		0		429000	63.34
JUN	48300	18	.127	1	0		0		223700	82	23.79	99	0		0		272000	23.92
JUL	81160	83	.1787	2	0		0		0		0		16240	17	8.882	98	97400	9.061
AUG	29420	86	.0512	4	0		0		0		0		4786	14	1.245	96	34206	1.296
SEP	10355	95	.0147	95	0		0		0		0		565	5	.008	5	10920	.02270
																		114.910

TABLE F-10 (Continued)

SITE ID: [illegible]

WATER YEAR: 1974

WATERSHED: LONELY GULCH CREEK

	[illegible]				STAGE 1				STAGE 2				RAINFALL				MONTHLY TOTALS	
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	TON/MO
OCT	[illegible]	95	[illegible]	95	0		0		0		0		565.3	5	.0008	5	10920	.01553
NOV																		
DEC																		
JAN																		
FEB																		
MAR																		
APR																		
MAY																		
JUN																		
JUL																		
AUG																		
SEP																		

TABLE V-13 (Continued)

SITE ID: GAUGE NO. 9

WATER YEAR: 1973

WATERSHED: LOVELY GULCH CREEK

	SNOWMELT				STAGE I				STAGE II				RAINFALL				MONTHLY	TOTALS
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	%	TON/MO	%	KL/MO	TON/MO
OCT																		
NOV																		
DEC																		
JAN																		
FEB																		
MAR																		
APR																		
MAY																		
JUN	0		0		219000	38	64.01	36	341300	59	58.31	39	14683	3	45.24	30	575000	148.6
JUL	349000	100	.8864	100	0		0		0		0		0		0		349000	.8864
AUG	77460	87	.161	1	0		0		0		0		11340	13	17.22	99	88800	17.38
SEP	11766	83	.0077	1	0		0		0		0		2414	17	.8731	99	14180	.8808

[illegible] (Continued)

SITE ID: [illegible]

WATER YEAR: 1979

WATERSHED: [illegible] CREEK

	BASEFLOW				STAGE 1				STAGE 2				RAINFALL				MONTHLY	TOTAL
	FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW		SEDIMENT		FLOW	SEDIMENT
	m3/mo	%	ton/mo	%	m3/mo	%	ton/mo	%	m3/mo	%	ton/mo	%	m3/mo	%	ton/mo	%	m3/mo	ton/mo
OCT	[illegible]	[illegible]	[illegible]	[illegible]	0		0		0		0		[illegible]	[illegible]	32.72	100	[illegible]	32.76
NOV	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0		0		0		0		27720	[illegible]
DEC	0		0		[illegible]	100	[illegible]	100	0		0		0		0		[illegible]	[illegible]
JAN	0		0		[illegible]	100	[illegible]	100	0		0		0		0		[illegible]	[illegible]
FEB	0		0		[illegible]	100	[illegible]	100	0		0		0		0		[illegible]	[illegible]
MAR	0		0		[illegible]	100	[illegible]	100	0		0		0		0		[illegible]	[illegible]
APR	0		0		[illegible]	100	[illegible]	100	0		0		0		0		[illegible]	[illegible]
MAY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0		0		[illegible]	2.694
JUN	[illegible]	[illegible]	[illegible]	100	0		0		0		0		0		0		[illegible]	[illegible]
JUL	[illegible]	[illegible]	[illegible]	[illegible]	0		0		0		0		0		0		[illegible]	[illegible]
AUG	[illegible]	[illegible]	[illegible]	[illegible]	0		0		0		0		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SEP	[illegible]	[illegible]	[illegible]	[illegible]	0		0		0		0		[illegible]	[illegible]	12.86	100	[illegible]	12.86
																		[illegible]

APPENDIX D

SOURCES OF EROSION CONTROL PRODUCTS AND SERVICES

Included in this appendix are lists of numerous commercial sources for erosion control plants, seeds, products and services which were used as part of the erosion control demonstration project or may be suitable for use in the Lake Tahoe Basin of California and surrounding areas. The lists are not complete and do not constitute a guarantee of reliability or quality of product or service. The California State Water Resources Control Board does not endorse any supplies or providers of services. No discrimination is intended by omission.

I. Plants and Seeds

Parts A, B, C, D, and E are listings of the various grasses, legumes, wildflowers, shrubs and trees, respectively, which were used as part of the erosion control demonstration project. Numerical designations following each plant species refers to the numerical listing of plant and seed suppliers contained in Part F.

A. Grasses

1. *Agropyron intermedium* (intermediate wheatgrass)
    - Greenar - 1, 2, 3, 17
    - Oahe - 1, 2, 3, 8, 14, 15, 16, 17
    - Tegmar - 27, 35
    - No variety given - 7, 12, 13, 18, 28, 31, 34
2. *Agropyron trichophorum* (pubescent wheatgrass)
    - Luna - 1, 2, 3, 7, 8, 14, 15, 18, 24, 28, 31, 34, 35
    - Topar - 1, 2, 3, 13, 17, 18, 24, 35
    - No variety given - 8, 12, 13, 28
3. *Bromus enermis* (smooth brome)
    - Manchar - 7, 8, 13, 14, 17, 18, 24, 28
    - Lincoln - 8, 12, 14, 17, 18, 24, 28, 33
4. *Dactylis glomerata* (orchard grass)
    - Potomac - 1, 2, 3, 7, 8, 13, 15, 17, 18, 24, 31, 33, 35

5. *Festuca ovina* (hard fescue)
    - Durar - 1, 2, 3, 7, 8, 13, 15, 17, 18, 24, 31, 33, 35

B. *Legumes*

1. *Astragalus cicer* (Cicer milkvetch)
    - Lutana - 2, 8, 13, 16, 28, 34
2. *Lotus corniculatus* (Birds foot trefoil)
    - Broadleaf - 1, 2, 3, 10, 12, 13, 14, 15, 17, 18, 31, 33
3. *Lupinus Spp*. (lupines)
    - 1, 3, 6, 9, 10, 19, 21, 22, 25, 26, 30, 31
4. *Trifolium repens* (white dutch clover)
    - 1, 3, 7, 8, 13, 17, 18, 24, 31, 33

C. *Wildflowers*

1. *Eschscholzia calif*. (California poppy)
    - 1, 3, 9, 10, 21, 22, 25, 30, 31, 36
2. *Gilia leptantha* (showy blue gilia)
    - 1, 3, 9, 10, 22, 25, 30, 31
3. *Linum perenne lewisii* (western blue flax)
    - 1, 3, 9, 10, 22, 25, 30, 31
4. *Nemophila maculata* (fivespot)
    - 1, 3, 9, 10, 22, 25, 30, 31
5. *Oenothera hookeri* (hooker's evening primrose)
    - 1, 3, 9, 10, 22, 25, 30, 31
6. Wild flower seed mixtures
    - 1, 3, 9, 10, 21, 22, 25, 30, 31

D. Woody Shrubs

1. Amelanchier alnifolia (service berry)
   - 11, 19, 25
2. Arctostaphylos nevadensis (pinemat manzanita)
   - 11, 22, 25, 26, 30, 34
3. Arctostaphylos patula (greenleaf manzanita)
   - 11, 19, 22, 25, 26, 30, 34
4. Artemisia tridentata (basin sagebrush)
   - 3, 5, 11, 21, 22, 25, 26, 30, 31, 36
5. Atriplex canescens (fourwing saltbush)
   - 2, 3, 5, 19, 21, 22, 25, 28, 30, 31, 33
6. Atriplex gardneri (Gardner's saltbush)
   - not commercially available
7. Castanopsis sempervirens (bush chinquapin)
   - 11
8. Ceanothus cordulatus (snowbush)
   - 11, 19, 25, 30
9. Ceanothus prostratus (squaw carpet)
   - 11, 19, 22, 25, 26, 29, 34, 36
10. Chrysothamus nauseosus (common rabbitbush)
    - 11, 19, 22, 25, 26, 28, 30
11. Cornus stolonifera (dogwood)
    - 11, 19, 25
12. Eriogonum umbellatum (sulfur flower buckwheat)
    - 3, 19, 22, 25, 26, 30, 31, 36

13. Lonicera conjugalis (double honeysuckle)

- 11, 25

14. Nama lobbii (wooly nama)

- not commercially available

15. Penstemon newberryi (mountain pride)

- 11, 20, 26, 29, 34, 36

16. Penstemon strictus (Rocky Mountain penstemon)

- not commercially available in California

17. Prunus emarginata (bittercherry)

- 11

18. Purshia tridentata (bitter brush)

- 3, 11, 19, 25, 26, 28, 30, 34

19. Rhamnus rubra (Sierra Coffeeberry)

- no commercially available

20. Ribes spp. (Currant, gooseberry)

- 11, 19, 25, 34

21. Rosa woodsia (Wood's rose)

- 11, 19

22. Rubus parviflorus (thimbleberry)

- 11, 19

23. Salix spp. (willow)

- 11

24. Symphoricarpos spp. (snowberry)

- 11, 19, 25, 34

E. Trees

1. Abies magnifica (red fir)

   - 3, 4, 9, 10, 11, 18, 19, 24, 25, 30, 31, 32, 34, 36

2. Abies concolor (white fir)

   - 3, 4, 9, 10, 11, 18, 19, 24, 25, 30, 31, 32, 34, 36

3. Calocedrus decurrens (incense cedar)

   - 3, 4, 9, 10, 11, 18, 19, 24, 25, 30, 31, 32, 34, 36

4. Juniperus occidentalis (western juniper)

   - 3, 4, 9, 10, 11, 18, 19, 24, 25, 30, 31, 32, 34, 36

5. Pinus jeffreyi (jeffrey pine)

   - 3, 4, 9, 10, 11, 18, 19, 24, 25, 30, 31, 32, 34, 36

6. Pinus lambertiana (sugar pine)

   - 3, 4, 9, 10, 11, 18, 19, 24, 25, 30, 31, 32, 34, 36

F. Plant and Seed Suppliers

The suppliers are listed in alphabetical order with numerical designations as referred to in preceeding parts A, B, C, D, and E.

1. Albright & Company, 3613 Brook St., Lafayette, CA 94549
   (213) 442-3330

2. Arkansas Valley Seeds, Box 270, Rocy Ford, CO 81067
   (303) 254-7469

3. Berger & Plate Co., 1 California St., San Francisco, CA 94104
   (415) 445-1553

4. California Division of Forestry Nursery, 5800 Chiles Rd.,
   Davis, CA 95616 (916) 753-2441

5. Carter, Roy, P. O. Box 4006, Sylmar, CA 91342 (213) 367-5811

6. Coates, Leonard Nurseries, Inc., 400 Casserly Rd.,
   Watsonville, CA 95076 (408) 724-0651

7. Curtis & Curtis, Inc., Star Rt., Box 8A, Clovis, New Mexico
   88101 (505) 762-4759

8. Eisenman Seed Co., Fairfield, Montana 59436 (406) 467-2521

9. Environmental Seed Producers, Inc., P. O. Box 5904, El Monte,
CA 91734 (213) 442-3330

10. Ferry-Morse Seed Co., Box 100, Mountain View, CA 94042
(415) 967-6973

11. Forest Farm, 990 Tetherow Rd., Williams, OR 97544
(503) 846-6963

12. Germain's, Inc., P. O. Box 12447, Fresno, CA 93777
(209) 233-8823

13. Jacklin Seed Co., 8803 E. Sprague Ave., Spokane, WA 99206
(509) 926-6241

14. Mile-High Seed Co., Box 1988, Grand Junction, CO 81501
(303) 242-3122

15. Miller Seed Co., P. O. Box 81823, Lincoln, Nebraska 68501
(402) 432-1232

16. Montana Seeds, Inc., Rt. 3, Conrad, Montana 59425
(406) 278-5547

17. North Coast Seed Co., P. O. Box 12185, Portland, OR 97212
(503) 288-5281

18. Northrup King & Co., P. O. Box 12123, Fresno, CA 93776
(209) 237-4731

19. Northplan Seed Producers, Box 9107, Moscow, Idaho 83843
(208) 882-8040

20. Outwater, Harry, P. O. Box 13709, South Lake Tahoe, CA 95702
(916) 544-5160

21. Payne, Theodore Foundation, 10459 Tuxford St., Sun Valley,
CA 91352 (213) 768-1802

22. Pecoff Bros., Nursery and Seed, Rt. 5 Box 215R, Escondido, CA
92025 (714) 744-3120

23. Perry's Plants, Inc. 19362 Walnut Drive, La Puente, CA
91745 (213) 964-1285

24. Ramsey Seed, Inc., P. O. Box 352, 260 S. Main, Manteca, CA
95336 (209) 823-1721

25. Robin Clyde, P. O. Box 2091, Castro Valley, CA 94546 (415)
581-3467

26. Saratoga Horticultural Foundation, P. O. Box 308, Saratoga, CA 95070 (408) 867-3214

27. Sasaki & Sasaki's Farm, Rt. 1, Box 173-B, Weiser, ID 83672 (208) 549-2434

28. Sharp Bros. Seed Co., Healy, Kansas 67850 (316) 398-2231

29. Siskiyou Rare Plant Nursery, 522 Franquette St., Medford, OR 97501 (503) 772-6050

30. S & S Seeds, 382 Arboleda Rd., Santa Barbara, CA 93110 (805) 967-6927

31. Stover Seed Co., 598 Mateo St., Los Angeles, CA 90013 (213) 626-9668

32. Tahoe Tree Company, P. O. Box 488, Tahoe City, CA 95730 (916) 583-3911

33. Valley Seed Co., P. O. Box 1110, Phoenix, AZ 85001 (602) 956-4656

34. Wapumne Native Plant Nursery, 8305 Cedar Crest Way, Sacramento, CA 95826 (916) 383-5154

35. Winterfeld, Delbert F., Box 97, Swan Valley, Idaho 83449 (208) 483-2248

36. Yerba Buena Nursery, 19500 Skyline Blvd., Woodside, CA 94062 (415) 851-1668

II. Erosion Control Products

The following is a partial list of erosion control products and manufacturers. The list is not complete and does not constitute a guarantee of reliability or quality of service or product. This list is not meant to endorse any product, and no discrimination is intended by omission. Products and manufacturers listed below are those which were:

- used as part of the demonstration project,
- similar to product used, or
- mentioned elsewhere in this report.

A. Wood Fiber Mulch

Silva-Fiber Mulch
Weyerhaeuser Co.
Tacoma, WA
(206) 924-2345

Conwed & Conwed 2000
Conwed Corp.
St. Paul, MN
(612) 222-3033

Necco Fiber
National Erosion Control Co.
Cotati, CA
(707) 795-9210

B. Straw and Mulch Tackifiers

Ecology Controls M-Binder
Ecology Controls
No. Hollywood, CA
(213) 877-7645

Dow XFS-4163-L
Dow Chemical, USA
Midland, MI
(517) 636-2086

Terra Tack II
Grass Growers, Inc.
Plainfield, NV
(201) 755-0923

Petroset Soil Binder
Phillips Chemical Co.
Bartlesville, OK
(918) 661-6600

C. Mulch Nets and Blankets

Excelsior
American Excelsior Co.
Sheboygan, WI
(414) 458-4333

Conwed Netting
Conwed Corp.
St. Paul, MV
(612) 222-3033

Jute Netting
Ludlow Textiles
Needham Heights, MA
(617) 444-4900

Hold-Gro
Gulf States Paper
Tuscaloosa, AL
(810) 729-5831

D. Fiber Glass Roving

Glassroot
Pittsburg Plate Glass Co.
Pittsburg, PA
(412) 434-3131

Landglas
Owens-Corning Fiberglass
Toledo, OH
(419) 248-8000

E. Gabions

Bekaert Gabions
Terra-Aqua Conservation
Reno, NV
(702) 329-6262

Maccaferri Gabions
Bellevue, WA
(206) 455-4567

III. Erosion Control Contractors

The following is a partial list of erosion control contractors who have hydromulching and/or mechanical straw mulching capability in northern California and northern Nevada. The list is not complete and does not constitute a guarantee of reliability of quality or service. This list is not meant to endorse any contractor, and no discrimination is intended by omission. Generally, other local landscape or nursery contractors are also available to perform other erosion control activities besides hydromulching or mechanical straw mulching.

A. Northern California

Cagwin and Dorward
San Rafael
(415) 454-3122

Valley Crest Landscaping, Inc.
Hayward
(415) 489-1179

Bibens
Modesto
(209) 545-1621

Coberly-Plumb
Visalia
(209) 732-2216

Enterprise Gardens
Redding
(916) 243-7170

North State Nursery
Ukiah
(707) 462-0553

Selby Soil Erosion Control
Vacaville
(707) 448-1664

Contra Costa Landscaping
Martinez
(415) 229-1060

Sunshine Landscapes
San Rafael
(415) 924-2844

Cal-Kirk
Eureka
(707) 822-1168

Econo-Garden
Oakland
(415) 638-4161

Gary Justice
San Ramon
(415) 837-2787

Sci-Soil
Tulare
(209) 586-0117

B. Northern Nevada

P & S Hardware
Reno
(707) 329-1392

Angelo Pecorilla
Carson City
(702) 883-1119

Howe Landscape
Reno
(702) 358-2888

Unrue Turf Farm
Minden
(702) 782-3146

APPENDIX E

GLOSSARY

abundance, species (richness): A measure of the variety of biologic species present in a community.

angle of internal friction: The maximum slope that an unconsolidated soil may assume.

angle of repose: The angle between the horizontal and the maximum slope that an unconsolidated soil material assumes through natural processes.

annual plant: A plant that normally lives for one year or less.

aspect: The direction that a slope faces.

asphaltic concrete (A - C): Asphalt and aggregate construction material for roadway pavement, shoulders, and dikes.

bed load: The sediment that moves by sliding, rolling, or bounding on or very near the stream bed.

bench: Gently sloping stable area at the toe of a steeper slope.

benthic: Of or pertaining to the bottom of streams, rivers, lakes, or oceans.

berm: A raised and elongated area of earth for erosion control intended to direct the flow of water or suspended sediment.

breast wall: A short retaining wall used for stabilizing the toe of eroding cut slopes.

Caltrans: California Department of Transportation; the branch of California State government responsible for the construction and maintenance of state and federal highways within California.

check dam: A small dam constructed in a gully or watercourse to decrease the streamflow velocity, minimize channel scour, and promote deposition of sediment.

contour: The shape of a land surface as expressed by contour lines.

contour line: (a) An imaginary line on the surface of the earth connecting points of the same elevation; (b) A line drawn on a map connecting points of the same elevation.

crown: The uppermost edge or edges of a slope.

cut and fill: A process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

deposition: The lying down of material because of reduction of carrying capacity.

detritus: In aquatic biology, disintegrated or fragmented organic matter which is carried to and deposited in a stream, river, lake, or ocean.

diversity (species): A measure of the relationship between the number of species and the total population of a biologic community; considered to be a very sensitive biological index of environmental change.

drill seeding: Planting seed with a mechanical device which places the seed at variable depths into the soil in relatively narrow rows, generally less than one foot apart.

drop-inlet (D.I.): A structure for collecting surface drainage which has been directed to it, and dropping the collected drainage water to an underground conduit.

eco-system: A community of organisms, its interrelationships, and the surroundings in which they live.

ecology: The interrelationship of organisms with other organisms and their environment.

equivalent cost: The cost of labor intensive erosion control techniques if conducted by skilled landscape laborers with a total labor cost of $16.25 per person-hour.

erosion: Detachment and movement of soil or rock by water, wind, ice, or gravity.

erosion hazard (rating): A rating system for determining the degree which land disturbance would increase erosion rate from a particular area.

evenness, species: A measure of the equality of apportionment of individuals in a biologic community to various species present.

fertilizer: Any organic or inorganic material of natural or synthetic origin which is added to a soil to supply certain elements essential to the growth of plants.

fertilizer grade: The guaranteed minimum analysis, in percent of the major plant nutrient elements contained in a fertilizer material. A 16-20-0 fertilizer refers to the percentage, by weight, of $N - P_2O_5 - K_2O$, respectively.

gabions: Rock filled, heavily galvinized wire mesh baskets used for the construction of breast walls, retaining walls, revetments, and groins.

grade: (a) The slope of a road, channel, or natural ground surface; (b) The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared for the support of construction; (c) To finish the surface of a canal bed, roadbed, top of embankment, or bottom of excavation.

gradient: The rate of regular or graded ascent or descent.

ground cover: Herbaceous vegetation and low-growing woody plants that form an earth cover.

grubbing: The process of removing roots, stumps, and low-growing vegetation.

gully erosion: The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths, ranging from 30 to 60 centimeters to as much as 170 to 250 centimeters.

hardpan: A hardened subsurface soil layer caused by cementation of soil particles with organic matter or with materials such as silica, sesquioxides, or calcium carbonate.

herbaceous: Vegetation that is nonwoody.

hydromulching: The mechanical application of a natural or synthetic mulch to a soil surface.

hydroseeding: The mechanical application of plant seeds to a soil surface in a water slurry, with or without fibrous mulch.

imperveous, impermeable: A material or device which is incapable of being penetrated or passed through by moisture or water.

indicator species: Specific organisms whose individual populations may be analyzed to determine the degree of stress on an entire ecosystem.

indigenous: Produced, growing, or living naturally in a particular region or environment.

infiltration: The flow of a liquid into a substance, such as soil, through pores or other openings; connoting flow into a soil in contradistinction to "percolation" which connotes flow through a porous substance.

innoculation: The process of adding cultures of symbiotic microorganisms to legume seed to enhance atmospheric nitrogen fixation.

Lahontan Regional Board: Regional Water Quality Control Board, Lahontan Region.

Lake Tahoe Basin: The 1,310 square kilometer watershed of Lake Tahoe (elevation 1,898 meters) in the Sierra Nevada Mountains of California and Nevada.

legume: A member of the plant family, Leguminosae, the fruit of which is usually a pod that opens along two sutures when ripe, leaves are alternate, have stipules, and are usually compound. Includes many valuable food and forage species such as peas, beans, peanuts, clovers, alfalfas, and vetches. Practically all legumes are nitrogen fixing plants.

Lonely Gulch Creek: A small creek draining a 237 hectare watershed on the west side of the Lake Tahoe Basin in California; the stream which flows through the Rubicon Properties development.

macroinvertibrates: Invertibrate animals generally larger than .5 millemeters which inhabit stream bottoms or are attached to stones or other objects in a stream.

mulch: Natural or artificial material used to provide more desirable moisture and temperature relationships for plant growth.

native plants or species: A plant or species that is a part of an area's original flora or fauna.

natural (background) level: The natural concentration of potential pollutants in the environment which would occur without the presence of man's activities.

Northstar-at-Tahoe: A well-planned and constructed 1,036 hectare all-year residental and recreational development in the West Martis Creek watershed north of the Lake Tahoe Basin in California.

overhang: The verticle, near verticle, or overhanging top section of a heavily eroded cut slope, usually retained by root systems of plants surviving above the cut slope.

parent material (soils): The unconsolidated, relatively unweathered mineral or organic matter from which the surface soils have developed.

percolation (soil water): The downward movement of water through soil, especially the downward flow of water in saturated or nearly saturated soil at hydraulic gradients of the order of 1.0 or less.

perennial plant: A plant that normally lives three or more years.

permeability: The capacity for transmitting a fluid.

perveous, permeable: Having the capability of being penetrated or passed through by moisture or water.

Porter-Cologne Water Quality Control Act: California state law enacted in 1970 which established the State Water Resources Control Board and established procedures, including the collection of monitory remedies, for maintaining high quality waters within the State.

profile, soil: A verticle section of the soil through all its horizons and extending into the parent material.

rainfall intensity: The rate at which rain is falling at any given instant, expressed in centimeters/hour.

retaining walls: Structure used to support and retain soil at an angle steeper than the angle of internal friction to provide a gently sloping soil surface above the structure.

Regional Water Quality Control Board, Lahontan Region (Regional Board): A branch of California State Government, headed by a nine member board, responsible for water quality control, subject to review by the State Board, within all watersheds to the east of the crest of the Sierra Nevada Mountains in California.

revetment: A facing of stone or other material, either permanent or temporary, placed upon a highly erodible, oversteepened slope to protect it from erosion.

rhizomatous: Having a root-like stem under or along the ground which sends out roots from its lower surface and leafy shoots from its upper surface.

riffle: A shallow portion of a stream with rapid turbulent flow.

right-of-way: Right of passage, as over another's property; a route that is lawful to use; a strip of land acquired for transport or utility construction.

rill erosion: An erosion process in which numerous small channels of only several centimeters in depth are formed.

rip rap: Broken rock, cobbles, or boulders placed on earth surfaces, such as the face of an oversteepened slope, for protection against erosion.

rounding, slope: The modeling or contouring of roadside and oversteepened slopes to provide a curvilinear transition between several planes; e.g., tops, bottoms, and ends of cuts and fills.

Rubicon Properties subdivision (Unit No. 2): An extremely poorly planned and constructed subdivision development on the west side of the Lake Tahoe Basin in California.

runoff: That portion of the precipitation on a drainage area that is discharged from the area in swails and stream channels. Types include surface runoff, groundwater runoff, or seepage.

scaling (slope): The process of reworking eroding cut and fill slopes to eliminate unstable conditions and prepare a surface suitable for the establishment of vegetation.

scarify: To abrade, scratch, or modify the surface; for example, to scratch the impervious seed coat of hard seed or to break the surface of the soil with a narrow bladed implement.

scour: The wearing away of channel substrate on stream beds.

sediment: Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, ice, or gravity.

sediment load: The quantity of sediment, measured in dry weight or by volume, transported through a stream cross section in a given time; sediment load consists of both suspended load and bed load.

sedimentation: The natural geologic or man-made process which includes erosion, transportation, and deposition of solid particles by wind, water, ice, or gravity.

seepage: Water escaping through or emerging from the ground along an extensive line or surface as contrasted with a spring where the water emerges from a localized spot.

settling basin: An enlargement in the channel of a stream or dammed area to permit the settling of debris carried in suspension.

slope: The degree of deviation of a surface from the horizontal, usually expressed in a ratio, percent, or degrees, such as 1½:1 (horizontal to vertical), 67 percent, or 34 degrees, respectively.

slough: Come off; fall away.

sprigging: The planting of a portion of the stem and/or root of a plant.

State Board: State Water Resources Control Board, California.

State Water Resources Control Board, California (State Board): A branch of California State Government, headed by a five member board, responsible for water rights, water quality, and water pollution control within the State.

standing crop: In aquatic biology, an estimate of the number of individuals per unit area in a community.

stilling basin: An open structure or excavation above a flow measuring device, such as a weir, to reduce the kinetic energy of the flowing water.

straw blowing: The application of straw mulch to a soil surface by means of a mechanical blower.

stream environment zone: Riparian area adjacent to streams containing sensitive vegetation and animal life.

subsoil: The stratum of material beneath the surface soil.

substrate: The bottom or benthic medium which biologic organisms inhabit.

swale: A hollow or depression.

tackifier: A chemical agent used to bind mulch fibers together.

tacking: The process of binding mulch fibers together by the addition of a sprayed chemical compound.

toe: The lower edge or edges of a slope.

tolerant (plants): Capable of growth and survival under competitive or adverse conditions.

topsoil: The upper layer of soil containing organic matter and usually suited for plant survival and growth. On a construction site, the topsoil should be saved for topsoiling.

topsoiling: The practice of replacing temporarily removed topsoil at a construction site once construction activities have been completed.

transpiration: The process by which water vapor is released to the atmosphere by the foliage or other parts of a living plant.

turbidity: An expression of the optical property of water which causes light to be scattered or absorbed due to the presence of suspended matter.

waste, construction: Excess sediment, earth, rocks, vegetation, or other materials resulting from roadway, residential, commercial, or other building construction.

water bars: Artificial barriers to divert surface runoff from erodible surfaces and to prevent accumulation of drainage water.

wattling, contour: Bundles of live, rooting plant species placed as partially buried "cables" across an eroding slope at regular contour intervals and supported at the lower side by stakes.

weathering: All physical, chemical, and biological changes produced in rocks at or near the earth's surface.

weir: An obstruction placed in a stream or channel diverting the water through a prepared aperture for measuring the rate of flow.

West Martis Creek: A small stream draining a 1,308 hectare watershed in the Truckee River watershed north of the Lake Tahoe Basin in California; the stream which flows through the Northstar-at-Tahoe development.

APPENDIX F

CONVERSION FACTORS[1]

Various conversion factors are included in this appendix for the convenience of the user of this report in calculating areas, rates, and volumes. Conversion factors are generally shown for four significant digits suitable for field use with a slide rule. For office calculations, more precise conversion factors of five or more significant digits may be needed in some instances.

UNITS AND EQUIVALENTS

Conversion Factors

To Convert	Into	Multiply By
	A	
acre	hectare	0.4047
	sq feet (sq ft)	43,560.0
	sq meters (sq m)	4,047.0
	sq miles (sq mi)	1.562×10^{-3}
acre-ft (ac-ft)	cu ft	43,560.0
	cu yds	1,613.0
	gallons (gal)	325,850.0
	cu meters (cu m)	1,234.0
	tons (short)	1,359.0
	C	
Celsius or Centigrade (C)	Fahrenheit (F)	1.8C + 32
centimeters (cm)	feet (ft)	0.03281
	inches (in)	0.3937
	meters (m)	0.01
	millimeters (mm)	10.0
cubic centimeters (cc)	cu ft	3.531×10^{-5}

1/ National Engineering Handbook, Chapter 10, Section 3, Soil Conservation Service, USDA, April 1971.

To Convert	Into	Multiply By
	cu in	0.06102
	U.S. gallons (U.S. gal)	2.642×10^{-4}
	liters (l)	0.001
	U.S. pints	2.113×10^{-3}
	U.S. quarts	1.057×10^{-3}
cubic feet (cu ft)	cu cms (cc)	28,320.0
	cu in	1,728.0
	cu meters (cu m)	0.02832
	cu yards (cu yd)	0.03704
	U.S. gallons (U.S. gal)	7.481
	liters (l)	28.32
cubic feet of water	pounds (lbs)	62.43
	kgs/sq cm	0.03048
	kgs/sq meter (kgs/sq m)	304.8
	pounds/sq ft (psf)	62.43
	pounds/sq in. (psi)	0.4335
cubic feet/sec (cfs)	acre-ft per day (ac-ft/d)	1.984
	acre-ft per year (ac-ft/yr)	724.0
	million gal's/day (mgd)	0.6463
	liters/sec (l/sec)	28.32
	cu m/sec	0.02832
cu ft/sec/sq mi (csm)	liters/sec/sq km (l/sec/sq km)	0.0915
cubic ft/sec (cfs)	gallons/min (gpm)	448.8
cfs-days	cu ft	86,400.0
cubic inches (cu in)	cu cms (cc)	16.39
	cu ft	5.787×10^{-4}
cubic meters (cu m)	cu ft	35.32
	U.S. gallons (U.S. gal)	264.2
	cubic yards (cu yd)	0.7645
cubic yards (cu yd)	cu cms (cc)	7.646×10^{5}

To Convert	Into	Multiply By
	cu ft	27.0
	cu meters (cu m)	0.7646
	U.S. gallons (U.S. gal)	202.0
	acre-ft	6.19×10^{-4}
	D	
days	second (sec)	86,400.0
deg F	deg C (Centigrade or Celsius)	(F° - 32).5556
	F	
Fahrenheit (F)	Centigrade (C)	(F° - 32).5556
feet (ft)	centimeters (cm)	30.48
	kilometers (km)	3.048×10^{-4}
	meters (m)	0.3048
	miles (mi)	1.894×10^{-4}
feet/min (fpm)	cms/sec (cps)	0.5080
	feet/sec (fps)	0.01667
	kms/hour (km/hr)	0.01829
	miles/hour (mi/hr)	0.01136
feet/sec (fps)	meters/min (m/min)	18.29
	miles/hour (mph)	0.6818
	km/hour (km/hr)	1.097
	G	
gal (U.S.)	cubic cms (cc)	3,785.0
	cubic feet (cu ft)	0.1337
	cubic inches (cu in)	231.0
	gallons Br. Imp. (gal Br. Imp.)	0.8327
	liters (l)	3.785
gallons of water (gal of wtr)	pounds of water (lbs of wtr)	8.3453
gallons/min (gpm)	cu ft/sec (cfs)	2.228×10^{-3}
	liters/sec (l/sec)	0.06308
	cu ft/hr	8.0208
gallons/acre (gal/A)	liters/hectare (l/ha)	9.353

To Convert	Into	Multiply By
grams (g)	pounds (lbs)	2.205×10^{-3}
gram of water (g of wtr)	cu cm of water (cc of wtr)	1.0 (at 4°C)
	H	
hectares (ha)	acres	2.471
	sq feet (sq ft)	1.076×10^{5}
hours (hr)	days	0.04167
	weeks (wk)	5.952×10^{-3}
	I	
inches (in)	centimeters (cm)	2.540
inches (watershed)	cu ft/sec/sq mi (csm)	13.584
	K	
kilograms (kg)	pounds, (lb) avoirdupois	2.205
	tons, short (T)	1.102×10^{-3}
kilograms/hectare (kgs/ha)	pounds/acre (lbs/A)	0.8921
kilograms/sec (kg/sec)	ton (short)/ year (T/yr)	34,786.0
kilometers (km)	miles (mi)	0.6214
	L	
liters (l)	cubic cm (cc)	1,000.0
	gallons U.S. (gal U.S.)	0.2642
liters/sec (l/sec)	cubic foot/sec (cu ft/sec)	0.0353
liters/sec/ sq km (l/sec/sq km)	cubic ft/sec/sq mi (csm)	10.93
liters/hectare (l/ha)	gallons/acre (gal/A)	0.1069
	M	
meters (m)	yards (yd)	1.094
	feet (ft)	3.281
	inches (in)	39.37

To Convert	Into	Multiply By
meters (m)	miles (stat) (mi stat)	6.214×10^{-4}
miles (U.S. stat) (mi)	kilometers (km)	1.609
miles/hour (mph)	feet/sec (fps)	1.467
milligrams/liter (mg/l)	parts/million (ppm)	1.000*
milliliters (ml)	liters (l)	0.001
millimeters (mm)	inches (in)	0.03937
	microns (u)	1×10^{3}
million gallons/ day (mgd)	cu ft/sec (cfs)	1.547
	acre-ft/day	3.069
	cu m/min	2.629
minutes (min) (angles)	degrees (deg)	0.01667
	O	
ounces (oz)	grams (g)	28.35
	pounds (lbs)	0.0625
ounces/gallon (U.S.) (oz/gal-U.S.)	gms/liter (gm/l)	7.489
	P	
parts per million (ppm)	milligrams per liter (mg/l)	1.000*
pounds (lbs)	grains	7,000.0
	grams (g)	453.6
	kilograms (kg)	0.4536
	ounces (oz)	16.00
	tons** (T)	0.0005
pounds of water (lbs of wtr)	cubic feet (cu ft)	0.01602
	cubic inches (cu in)	27.68
	gallons (gal)	0.1198
pounds of water/min (lbs of wtr/min)	cu ft/sec (cfs)	2.670×10^{-4}

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* True within one percent when the concentration is less than 10,000 ppm.

** Throughout this report, tons means metric tons (2,205 lbs) unless otherwise indicated as tons (short) or tons (long).

To Convert	Into	Multiply By
pounds/cu foot (pcf)	grams/cu cm (g/cc)	0.01602
	kgs/cu meter (kg/cu m)	16.02
	pounds/cu in (pci)	5.787×10^{-4}
pounds/cu in (pci)	gms/cu cm (g/cc)	27.68
pounds/gallon (U.S.)	gms/liter (g/l)	119.8
pounds/acre (lbs/A)	kilograms/hectare (kgs/ha)	1.121
	R	
rods	feet (ft)	16.50
	miles (mi)	3.125×10^{-3}
	S	
sq centimeters (sq cm)	square inches (sq in)	0.1550
square feet (sq ft)	acres (ac)	2.296×10^{-5}
square inches (sq in)	sq cms	6.452
sq kilometers (sq km)	sq miles (sq mi)	0.3861
square meters (sq m)	sq ft	10.76
square miles (sq mi)	acres (ac)	640.0
	square feet (sq ft)	27.88×10^{6}
	square kms (sq km)	2.590
	square meters (sq m)	2.590×10^{6}
	square yards (sq yd)	3.098×10^{6}
square yards (sq yd)	square feet (sq ft)	9.0
	square meters (sq m)	0.8361
	T	
tons* (long) (T)	pounds (lbs)	2,240.0

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* Throughout this report, tons means metric tons (2,205 lbs) unless otherwise indicated as tons (short) or tons (long).

To Convert	Into	Multiply By
tons* (metric) (T)	kilograms (kg)	1,000.0
	tons (short) (T)	1.102
	pounds (lbs)	2,205.0
tons* (metric)/ sq km (T(met)/sq km)	tons (short)/ sq mi	2.854
tons* (short)	kilograms (kgs)	907.2
	pounds (lbs)	2,000.0
	tons (long)	0.8929
	tons (metric)	0.9078
tons (short)/ sq mi	tons (metric)/ sq km	0.350
	tons (short)/acre	1.5625×10^{-3}
	W	
watershed in watershed inches	acre-ft/sq mi	53.33
	acre-ft (total)	53.33 x drainage area (in sq mi)
	Y	
years (yr)	seconds (sec)	31.5576×10^{6}

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* Throughout this report, tons means metric tons (2,205 lbs) unless otherwise indicated as tons (short) or tons (long).